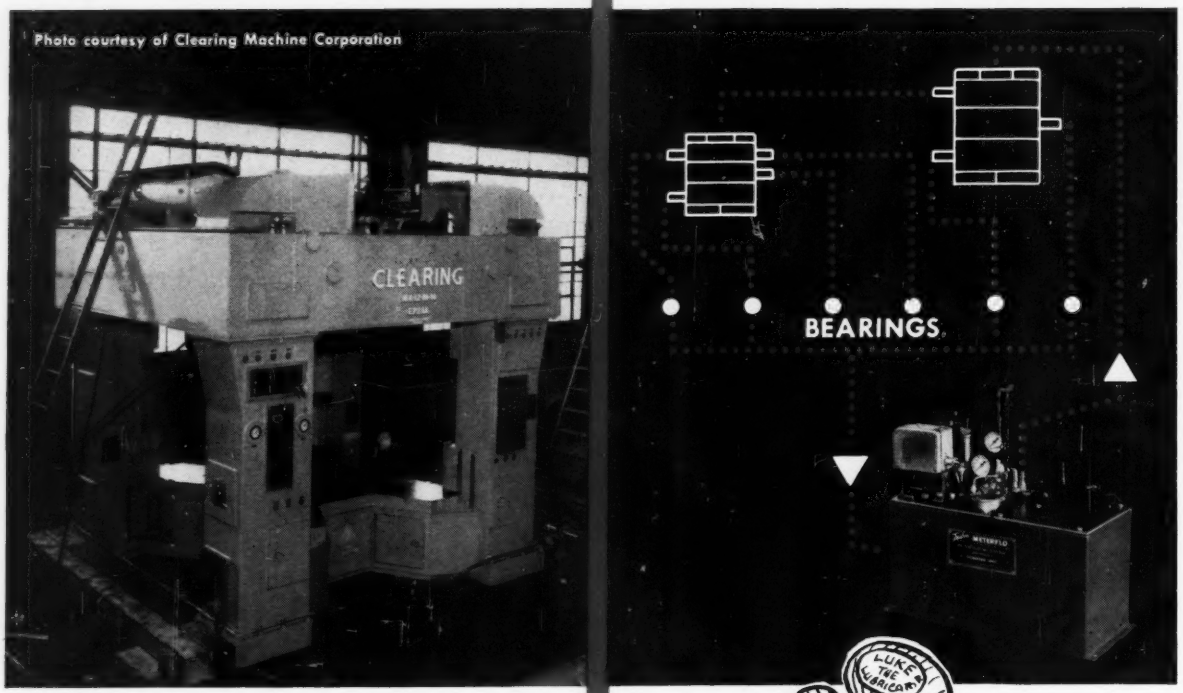
Practical Feature: REVIEW OF SYNTHETIC LUBRICANTS

APRIL, 1954
Vol. 10, No. 2

Lubrication ENGINEERING

9th ASLE Annual Meeting & Exhibit Issue

JOURNAL OF
THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS



Trabon's METERFLO OIL CIRCULATING SYSTEM *ELIMINATES TROUBLE*

ON 20-TON WELDING PRESS

This is one of an installation of 36 four-point welding presses in a large automotive plant, all automatically lubricated by TRABON METERFLO systems.

TRABON *positive* lubrication assures all of the 68 bearing points on each press the right amount of filtered oil at the right time. Remote indicating gauges are mounted in the left-hand corner column of the presses for easy visibility. Warning lights flash on in the event of interrupted flow of oil to the bearings.

This installation is typical of the thousands of TRABON automatic lubrication systems in operation in industry everywhere . . . under all manner of operating conditions, indoors or outdoors, underground or on the surface.

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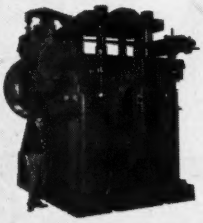
Oil and Grease Systems



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REGARDLESS OF THE SIZE AND TYPE OF YOUR MACHINERY, LUBRIPLATE GREASE AND FLUID TYPE LUBRICANTS WILL IMPROVE ITS OPERATION AND REDUCE MAINTENANCE COSTS.

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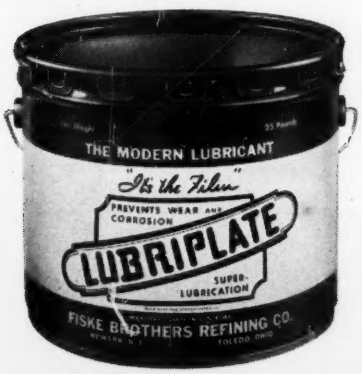

Lubrication ENGINEERING

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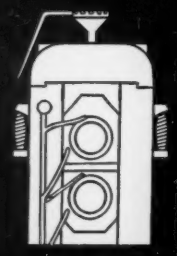
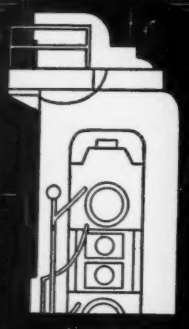
ROLL NECK BEARINGS



2-HIGH



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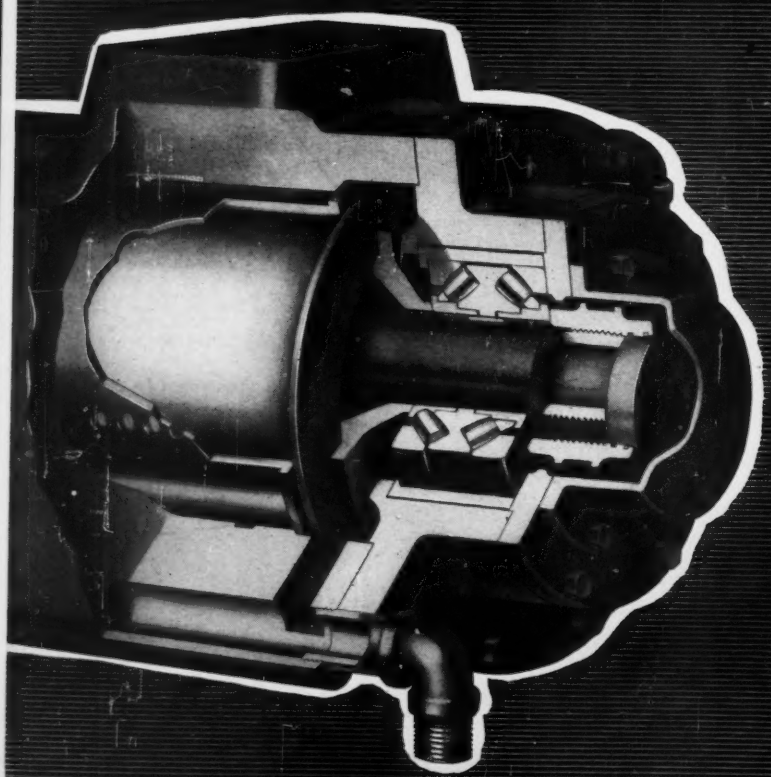

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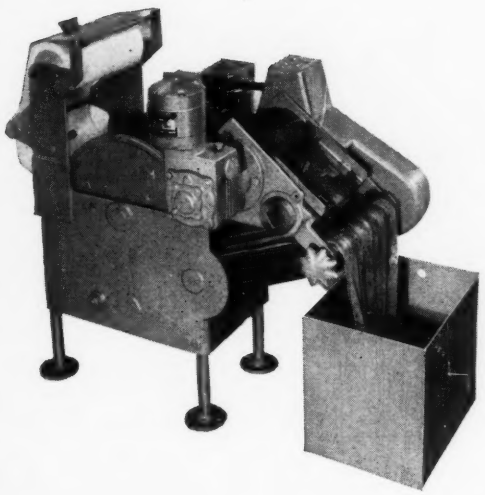

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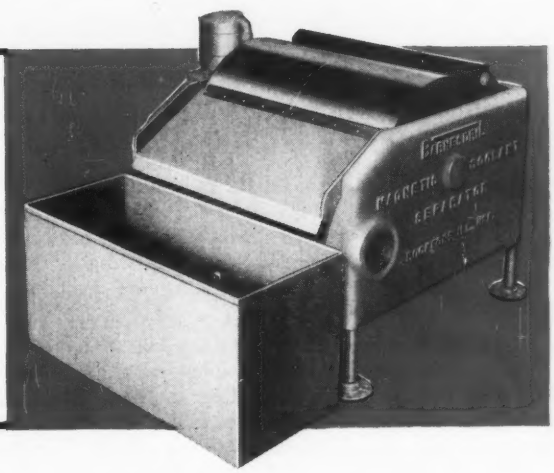

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- **resists oxidation**
- **will not squeeze out**
- **extends periods between overhauls**
- **provides exceptional lubrication in high or low operating temperatures.**

Shell Alvania Grease can cut down costly maintenance and save time and money in *your* plant. Write for technical information.

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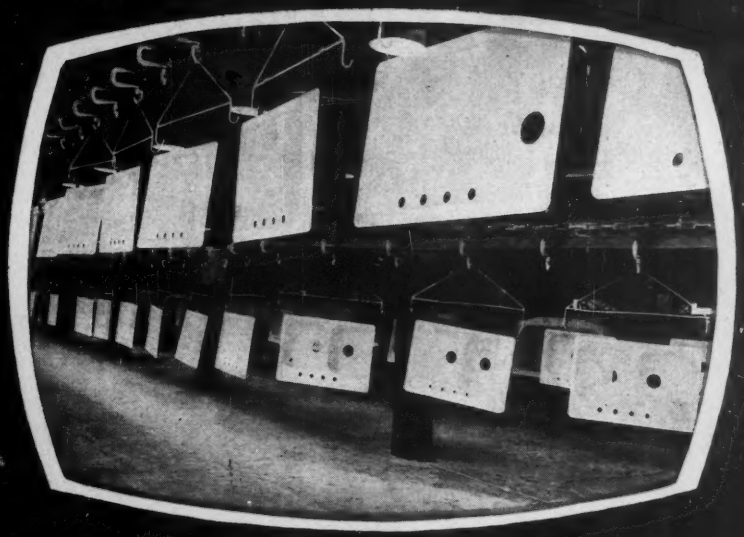
telling the story of 'dag' dispersions



Are You Getting Proper Results From Your Present Lubricant?

Does your present lubricant adhere to, and become an integral part of, all friction surfaces that move in high temperature? Does it possess almost unlimited durability? Does it provide protection at extreme temperatures to such things as bearings of kiln-car wheels, to oven conveyors, and other devices and appliances which are exposed to burning heat or freezing cold?

If your present lubricant cannot fulfill these varied requirements, then consider one which does: **'dag'** Colloidal Graphite, the ideal *dry-film lubricant.*

Dispersions of **'dag'** Colloidal Graphite in oils, water, volatile hydrocarbons, and resin-solvent combinations give you slick, durable, dry lubricating films. Applied by spraying, painting, or dipping, they won't gum up or break down *at any temperature you are likely to encounter.*

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Dispersions of molybdenum disulfide are available in various carriers.

We are also equipped to do custom dispersing of solids in a wide variety of vehicles.

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... also ACHESON COLLOIDS LIMITED, LONDON, ENGLAND

try 'dag' resin bonded dry films for permanent lubrication

This symbol identifies the National Machine Tool Builders' Association—a group of 196 manufacturers of machine tools. 148 of these companies, or 3 out of 4, are using Garlock KLOZURE Oil Seals.

3 out of 4

Machine Tool Builders use KLOZURE* OIL SEALS

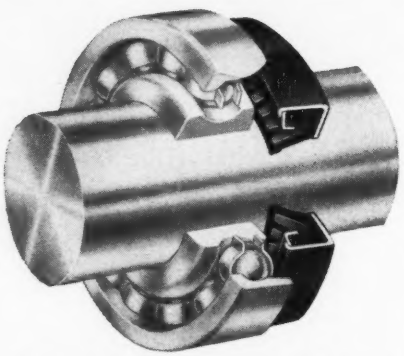
Here are 3 reasons why—

1. The KLOZURE Oil Seal is a precision-made product, so necessary for all components of the tools which are designed for fine precision machining.

2. KLOZURES are *uniform*—both in sealing contact and in spring load.

3. KLOZURE Oil Seals are extremely *efficient*—they provide effective sealing with a minimum of power loss and heat generation.

For positive bearing protection specify KLOZURE Oil Seals for your machinery. KLOZURES are made in many models and a complete range of sizes. Get all the facts—call your Garlock representative or write for KLOZURE Catalog No. 10.



Model 53 finger spring KLOZURE, for normal and high speed service, applied to a shaft to protect the ball bearing.

Model 51 — A general purpose finger spring seal for medium speeds.

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Model 65 — A general purpose garter spring seal for normal and high speed service.

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BY THE MEASURED DROP

the most dependable method of lubrication ever developed!

This lubricator becomes an integral part of a machine tool in which there are 48 vital bearings that require dependable lubrication. The Madison-Kipp mechanism is so compact that the reservoir measurements are only 4" wide, 19¾" long by 5¾ high."

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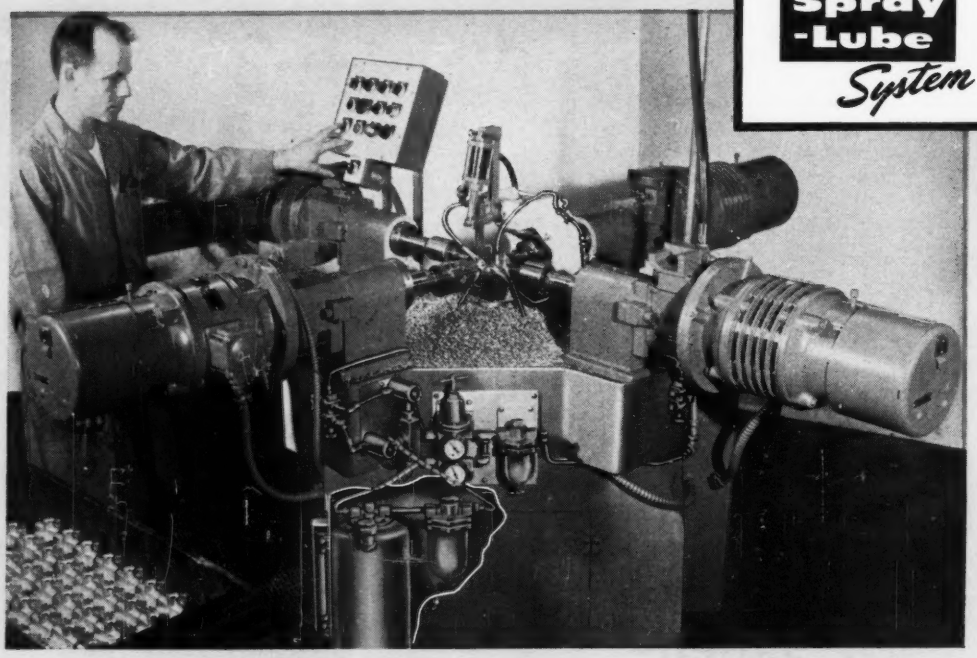

gives more efficient application of cutting oils for

- ***higher cutting speeds***
- ***faster rate of feed***
- ***longer tool life***
- ***lower unit production costs***

on tapping machines, drill presses, milling machines, grinders, lathes, boring machines, high-speed saws, stamping presses, deep draw presses.

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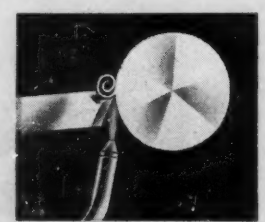

Coolant where you need it... spray is applied to work area from any required direction to thoroughly lubricate critical areas of contact between cutting tool and work piece.

A Drop of Coolant

A Drop of Coolant SPRAYED

Fine spray rapidly dissipates heat... the spray lubricates tool more efficiently; has greater exposed oil surface area for fast, thorough dissipation of heat.

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Complete lines of automotive, farm and industrial lubrication equipment and accessories.

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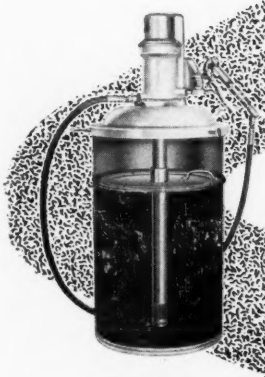

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THE LONG-LIFE LUBRICANT FOR YOUR MULTI-PURPOSE USE . . .

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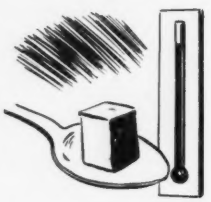
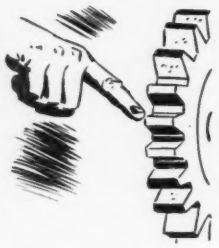


HEAT STABILITY—The consistency-temperature characteristics of Bentone greases are far superior to those of conventional greases. They will not melt below the decomposition point of the oil.



METAL ADHESION—The adhesion of Bentone greases to moving metallic surfaces is one of their best properties—far superior to all conventional greases. A grease may have many excellent properties, but if it fails to adhere to moving metallic or other surfaces, it is useless.

LONGER SERVICE LIFE—The mechanical and chemical stability of Bentone greases is excellent, with superior resistance to bleeding and separation, with wear characteristics comparable to those of the best grease products.

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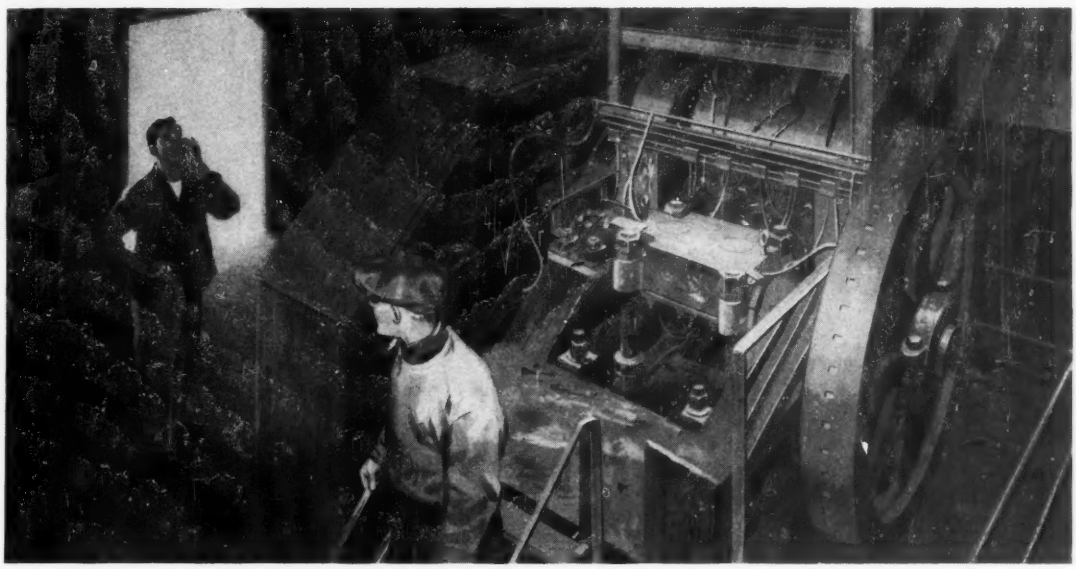
Call your nearest Bentone 34 grease distributor today*

FOR COMPLETE INFORMATION ON BETTER LUBRICATION

Bentone*34 greases *better*
for longer trouble-free service life!



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HERE'S WHAT BENTONE* 34 GREASE USERS SAY . . .

"During 12-month test on 4′ x 5′ jaw crusher, using a Bentone grease, reduced grease consumption by 4,837 pounds; an annual savings of $2,728 in grease cost over grade of grease formerly used."

"Grease clean-up time has been reduced 156 man hours per year, and 78 hours of operating time per year formerly lost for hot toggles have been eliminated."

Bentone* 34 multi-purpose lubricants can save your plant time and money too, where dust, heat, water, steam and extreme pressures are a problem.

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*TRADEMARKS REGISTERED U. S. PAT. OFF.

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THE NON-SOAP GELLING AGENT

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helps you design the advantages of

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into any machine...in minutes!

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It's easy to measure the lubrication requirements of *any* machine you are designing! Just set the Oil-Mist slide rule as required—for anti-friction bearings, plain bearings, slides, ways, vees, chains or gears—and immediately the proper application information appears.

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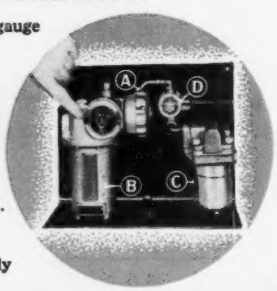
Save time and work in specifying and detailing Oil-Mist, the most efficient machine lubrication ever devised! Clip, fill out and mail coupon NOW. Supply limited!

Alemite Oil-Mist offers these lubrication advantages

Automatic Lubrication • Continuous Lubrication Eliminates Guesswork • Greater Safety • Cuts Oil Consumption up to 90% Extension of Bearing Life • Stops Oil Drippage • Reduction of Bearing Temperatures • Manpower Savings • Elimination of "Down-Time" Reduction in Number of Lubricants • Protection from Contamination

LUBRICATOR SPECIFICATIONS:



- Oil-Mist outlet ½" fem. p.t. Air gauge registers to 50 psi. Operating air pressure—5 to 20 psi.
- Air regulator (A) reduces from pressures up to 200 psi. Normal air consumption—.7 to 1.2 cfm.
- Range of oils handled—to 1,000 sec. (S.U.V.) @ 100°F.
- Oil reservoir (B) capacity 12 oz. (approximately 1 week supply). Intake filter screen—70 mesh. Fill plug—9/16".
- Material—die cast aluminum body with nylon plastic window.
- Baffle-type water separator (C)—automatic self-dumping. Requires no manual attention—no filter elements to replace. Air inlet ¼" fem. p.t.
- Solenoid Control (D) starts system automatically when machine starts—foolproof.

A PRODUCT OF SW STEWART WARNER

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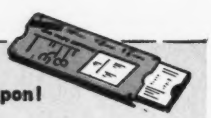

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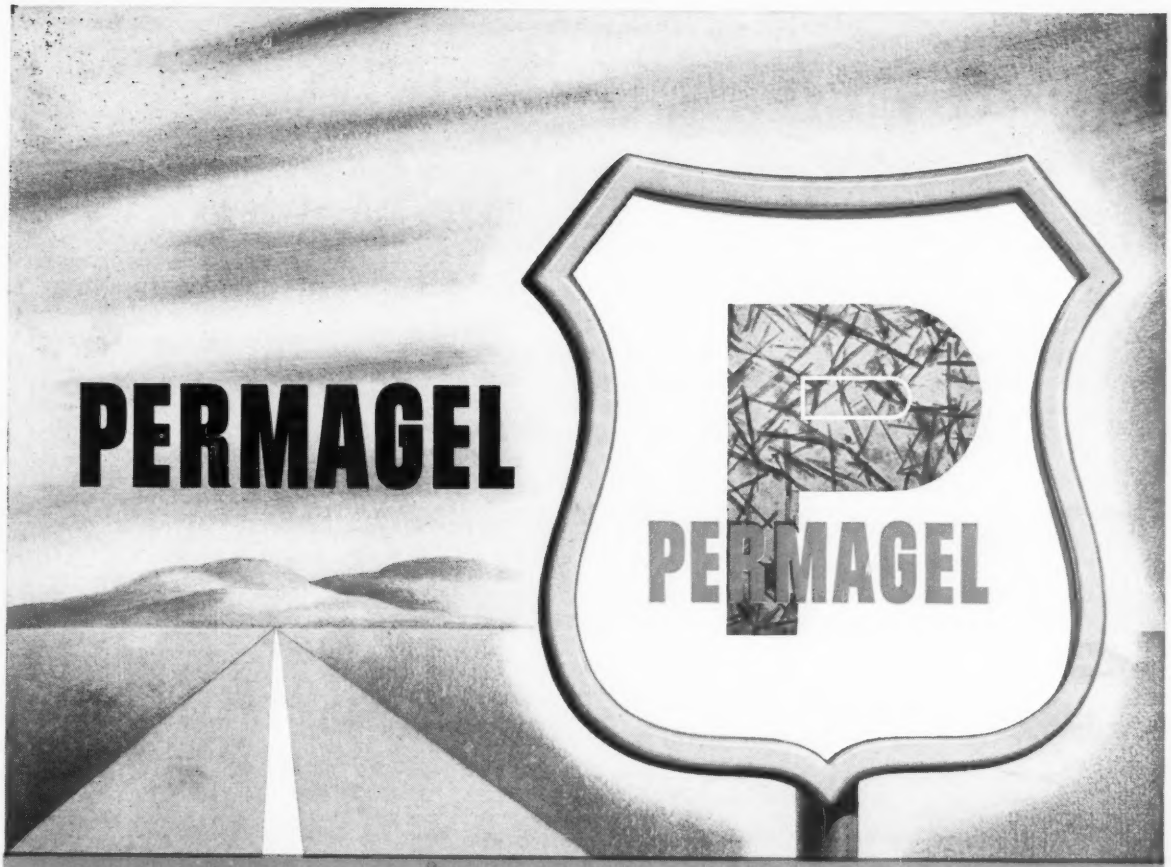

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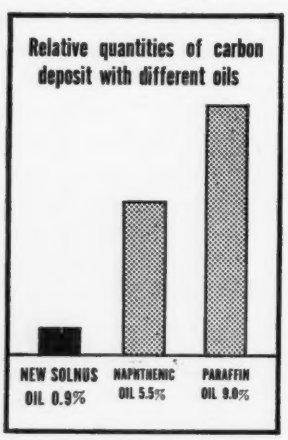

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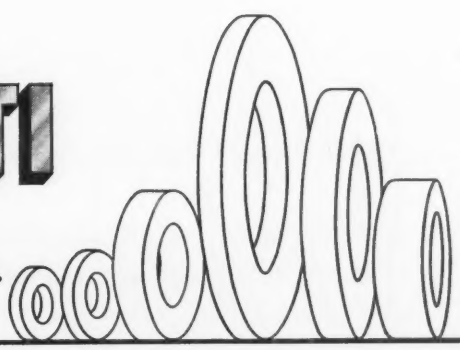

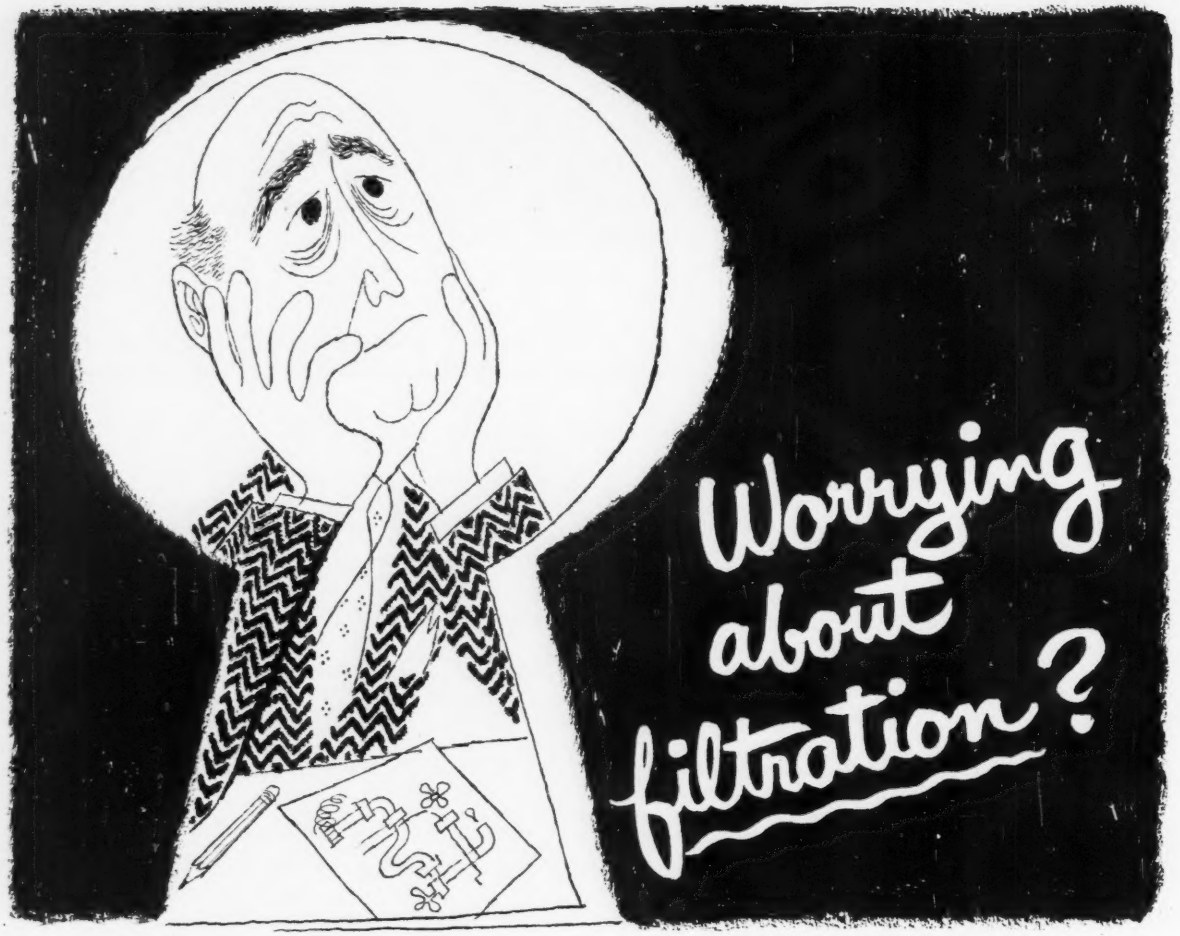

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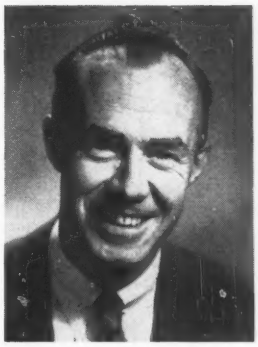
Practical Lubrication, No. 12

REVIEW OF SYNTHETIC LUBRICANTS*

by D. H. Moreton
Douglas Aircraft Co.
3000 Ocean Park Blvd.
Santa Monica, California



ABSTRACT: Seven principal classes of synthetic lubricants, the monobasic acid esters, dibasic acid esters, phosphate esters, silicones, silicate esters, polyglycol ethers and their derivatives, and halogenated materials are discussed. Their general physical and chemical properties, stability, lubricity, solvent effects, flammability, etc., are compared with petroleum products. Applications where particular properties of each class permit it to excel are shown. Costs and probable future trends of each type are considered. A table comparing the properties of the classes and a bibliography are included.

As an introduction to synthetic lubricants, it might be well to start with a list of questions which appear most frequently in connection with this subject. Such a list would include the following:

(1) What are synthetic lubricants?
(2) Why use them instead of petroleum?
(3) Why are they so expensive?
(4) Will they get cheaper?
(5) Will they replace petroleum oils?
(6) Do they lubricate as well as petroleum?
(7) Do they break down in use?
(8) Can they be interchanged with petroleum lubricants?
(9) Can they be mixed with petroleum lubricants?
(10) Are they good rust preventives?
(11) What about packing, gaskets and paint?
(12) How do they compare with specially-compounded petroleum oils?
(13) How do the military services regard synthetics?
(14) What type of synthetic is best for my use?
(15) Where can I get more information on them?

The above partial list of questions on synthetic lubricants covers those which I think research organizations and others concerned with such activities would agree appear most frequently. It seems quite apparent that the primary standard of comparison for the user is his present lubricant which is, in most cases, a petroleum product, and this is essentially a good basing point for an evaluation of the field of synthetic lubricants.

It is well known that the wheels of the last war were largely lubricated with petroleum-type hydrocarbons, and it is almost equally apparent that this will continue to be the case in any war in the foreseeable future. The same generalization can be made for the industrial use of lubricants. It is becoming increasingly clear, however, that the high performance required of many of our machines of war, and for that matter, many of our peacetime uses of machinery, is beginning to highlight those shortcomings of petroleum lubricants which point up the need for newer materials to do the job.

To assign a historical date for the inception of synthetic lubricants would be meaningless, since many of the materials which are used to reduce friction and to oil the wheels of industry were in use before petroleum was discovered. As a practical matter, however, the large-scale research activities and the tangible use of synthetics for purposes of industrial and military machinery lubrication probably do not date further back than 10 to 15 years.

What are synthetic lubricants? The question of what constitutes a synthetic lubricant is too broad to possibly cover in one writing. Synthetic lubricants include many materials and are generally characterized by having at least some properties which are similar to petroleum lubricants. They may be specific synthesized hydrocarbons, or more properly they cover oily neutral liquid materials not usually obtained directly from petroleum. Many of them now in use, or indicated for future use, have been previously known to industries other than the lubrication industry. They include plasticizers, many organic solvents, certain ester compounds, polymers, and formulations of some of the above materials. Some specific chemical classes are (1) monobasic acid esters; (2) dibasic acid esters; (3) the organophosphate esters; (4) silicone polymers; (5) silicate esters; (6) polyglycol ethers and related compounds; and (7) fluorinated and chlorinated hydrocarbon compounds.

It is apparent that the field outlined above is so broad that a general review can hope only to answer the principal questions that usually arise on the subject.

We will attempt to outline in the following pages the general properties of some of these synthetic lubricants, principally as compared with petroleum lubricants intended for the same usages. In general, the physical and chemical properties of the various classes of synthetics will be briefly covered and some remarks will be found on their availability and indicated fields of usage.

Why use them instead of petroleum? This brings us to our second question posed above, and perhaps the most important one of all: Why use them instead of petroleum? It is rare indeed when a user-industry will change from one lubricant to another of a totally different type unless he has found complete dissatisfaction with the one which he is now using, has changed his operating conditions to an extent where his present lubricant no

*Paper presented at the ASLE Los Angeles Section Meeting, Oct. 1952, and the Northern California Section Meeting, Sept. 1953.

longer does the job, or unless he is designing a new machine in which the operating conditions are so severe that the lubricant he is now using will no longer be satisfactory. This, of course, is sometimes a matter of opinion, and sometimes a matter of fact. The principal reason for choosing a lubricant of a synthetic nature is usually found in one of the two latter reasons noted above. In most cases, the lubricant in prior use, or on which presently available knowledge is based, is a petroleum lubricant, but in many cases it may not be the best petroleum lubricant that is available.

When such a doubt exists we are prompted to make the following recommendation:

A synthetic lubricant of a totally new or different nature should not be chosen over a readily-available and invariably lower initial-cost petroleum lubricant if the conditions under which the machine is operating, or the severity of duty-cycle in the machine itself, do not provide clear and compelling reasons for the choice of the synthetic.

This may seem to be a strange recommendation from a source whose principal activity over the past several years has been concerned with the synthesis and evaluation of synthetic functional fluids for use as lubricants and hydraulic fluids. Many examples have presented themselves where the glittering physical properties of some of the synthetic lubricants have caused them to be chosen for what appeared to be an almost hopeless task for a petroleum product. In the final analysis, however, it has often been found that a different petroleum product, perhaps a specially-compounded one, would do the job, and at a much lower cost. This is particularly so in the light of many other considerations which may present themselves in the use of a synthetic. An initial enthusiasm for new and unusual materials is understandable, but many new fields of endeavor have suffered an inordinate amount of criticism from the public or technical users because of misapplication of an otherwise useful product. The plastics industry has provided us with many examples of such an approach.

Having elaborated on why not to use synthetics, let us examine several reasons why or where they should be used. There are literally thousands of reasons which any good research technician could conjure up justifying the use of a synthetic-type lubricant over a conventional petroleum lubricant. This immediately makes it difficult to pick out the best reasons, particularly since this discussion constitutes more of a review than of a prediction of things to come. Probably the largest single reason, however, that has presented itself so far has been a general increase in the range of temperatures under which lubricants are expected to perform. The rapidly expanding transportation industry has carried us further into the remote cold and hot regions of our globe. The current speed-up in our highly industrialized country is inducing a similar increase in the severity of operating conditions in many of our machines of production, and certainly the far-flung, high altitude operations of our military forces have brought demands for increased operability at extremely low temperature. This demand for lubricants to serve at temperatures from below -65F., to temperatures as high as +400F., sometimes in the same machine, has clearly revealed that a petroleum product with sufficiently low viscosity to be mobile

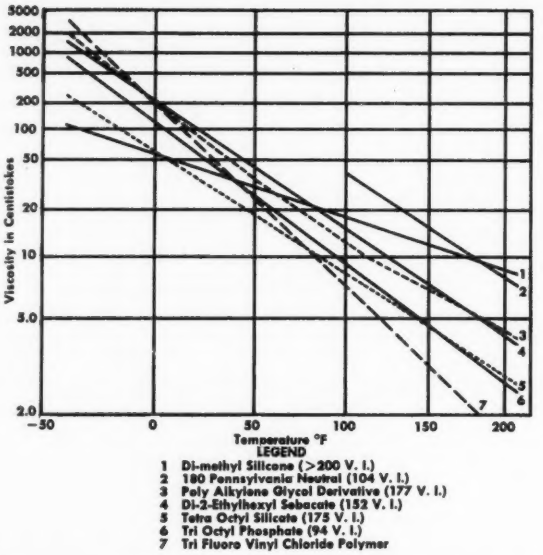


Fig. 1 Viscosity — Temperature Properties of some synthetic lubricants. (Plotted on ASTM Viscosity — Temperature Chart for liquid petroleum products.)

at extremely low temperatures will be susceptible to high volatility losses at high temperatures. Conversely, while some high molecular weight hydrocarbons have been sufficiently stabilized for use at temperatures in the order of 300 to 400F., these same materials are rarely usable at temperatures much below 0F. This simple fact has proved to be the most compelling reason favoring the use of esters and other synthetics in many new devices. Most of the synthetic lubricants that have been proposed for use so far show appreciably lower viscosity for a given volatility than equivalent petroleum materials, and conversely, if picked for the same viscosity properties, they usually have considerably lower evaporation rates than the hydrocarbon-type lubricants.

An example of the low volatility of the synthetics is shown in Table 1. In this table the weight losses by evaporation are shown for some of the dibasic acid esters made from organic acids of 5, 6, 9 and 10 carbon atoms esterified with hexyl and octyl alcohols. It can be seen that the lowest molecular weight ester in this group lost less than 5 weight per cent in 168 hours at 150F. Viscosities at low temperature in these samples ranged from 219 centistokes at -40F., to 1410 centistokes. Petroleum oils of comparable viscosity at low temperature could be expected to lose at least 10 weight per cent in such a test and perhaps as high as 25 per cent.

There are other reasons for the uses of some of the classes of synthetic lubricants. Some have extremely high chemical lubricity properties; others have very good thermal stability. Still others have better oxidation resistance than petroleum oils. Several of the classes of synthetics that have been suggested as lubricants, and some of which are in actual service, have excellent fire-resistant properties. In cases of extreme fire hazard, this factor can be a strong reason for their selection. Most of the new classes of synthetics proposed have much better viscosity-temperature characteristics than the best petroleum hydrocarbons; that is, higher viscosity index or a lower ASTM slope.

Fig. 1 illustrates a plot of viscosity-temperature

characteristics for various synthetic lubricant types as compared with one of the best petroleum lubricants, judged from the standpoint of V.I. It can be seen that at least some of these members of the synthetic lubricants field have considerably better viscosity-temperature characteristics. In other cases, an added advantage of many of the synthetics is their good solubility or dissolving power for additives, such as viscosity index improvers, oxidation inhibitors, rust inhibitors, etc. For these same reasons, they often have a high degree of natural detergency, and in many systems the oil is called upon to act as a scavenging agent for dirt and fuel deposits and many other insoluble residues which the oil is expected to pick up and carry to the filter. In spite of all of these other comparative advantages for the synthetic lubricants, it is probably still safe to say that the viscosity-volatility relationship has proved to be the strongest incentive for their use to date.

Why are they so expensive? Question #3 immediately raises the point in the mind of the potential user of what the expense of an oil involves. In initial cost the synthetics are, as a general rule, far higher than the petroleum products which they replace. While this difference will grow smaller in most classes of synthetics as the volume use of the product increases, it is unlikely that they can ever compete in initial cost with a lubricant such as petroleum which, despite high exploration costs, is quite readily pumped from the ground and processed into usable form. In fact many of the synthetics which are coming into use today are, or will be, available through the processing of petroleum fractions. Such a class of synthetics are the dibasic acid esters previously mentioned. These esters are the result of a reaction between an organic acid such as adipic acid and an alcohol, preferably of a high molecular weight, such as octyl alcohol. Adipic acid, for instance, can be made from benzene, butadiene or cyclohexene, all of which are derived from petroleum. Iso-octyl alcohol is in commercial production from petroleum sources through the Oxo process. In this process a selected petroleum olefin is reached with carbon monoxide and hydrogen to produce an aldehyde. This is further hydrogenated to the alcohol. Many other types of synthetics and starting materials for synthetic lubricants are available from reactions such as this. It is important to note, however, that in almost all cases more steps are necessary, more careful processing is required, and in general considerably more expense is involved in processing this same raw material source into the finished product than is now the case in the refining of crude oil into our present petroleum lubricants. This, of course, results in a product of higher initial expense and will probably continue to do so until and unless the quantities required serve to accelerate research for a simpler method of manufacture. It is unlikely, however, that this research will produce synthetics of the high degree of simplicity and purity with which we are now familiar.

It should be remembered that the high lubricity, good oxidation resistance and excellent thermal stability of some of the various classes of synthetics have in some cases already resulted in an extension of the working life of the lubricant, or an improvement in the life or efficiency of the machine to an extent where the over-all cost is lower than its cost of operation on a petroleum product. In considering the use of a synthetic, the initial cost should always be balanced against the possible economies that could be obtained through its use.

Ester	Molecular Wt.	% Wt. Loss From Evaporation★	Viscosity at −40°F (cs.)
Di-2-ethylhexyl Glutarate	356.5	4.6	715
Di-2-ethylbutyl Adipate	314.5	0.34	219
Di-2-ethylhexyl Adipate	370.6	0.07	807
Di-2-ethylbutyl Azelate	356.5	0.05	500
Di-2-ethylhexyl Azelate	412.5	<0.05	1190
Di-2-ethylhexyl Sebacate	426.7	<0.05	1410

★After heating 168 hours at 150°F in a convection-type oven

Table I Evaporation of some dibasic acid esters.

Will they get cheaper? To specifically answer Question #4 we believe the foregoing discussion indicates that the answer is yes. On the other hand, it is equally probable that most of the synthetics will never compete in initial cost with petroleum hydrocarbons.

CLASSES OF SYNTHETIC LUBRICANTS.

The balance of the questions involved in our opening remarks are best answered through a brief survey of the principal classes of synthetics already outlined. This review would be misleading if it did not first deal with a few of the general characteristics of the synthetics which require that they be introduced into present machines or designed into new machines with a careful understanding of many of their chemical properties. For instance, many of the synthetics are strong chemical solvents. The advantages of this property have been pointed out, but the disadvantages can far outweigh them if not considered in their use. They have a strong plasticizing effect on many of the synthetic rubbers and plastics now in use in our industrial world. The majority of the synthetics are better solvents for paint and paint-like substances than petroleum oils and unless proper precautions are taken, this can, at the very least, result in a nuisance item. On the other hand, for most of the synthetic lubricants there is at least one, and sometimes more, rubber-like materials which can be used for gaskets or sealing mechanisms, and similarly there are paints, wire coatings and other industrial finishes which have been found resistant to the strong solvent action of these materials. Some of the synthetics, such as the silicones and silicates, are rather poor solvents for many of the rubber-like materials used in industry. This can result in a hardening effect on gaskets and seal materials which is equally capable of causing leakage in the machine. In general, the solvency propperties of synthetic lubricant materials should be carefully considered before introduction into a machine not specifically designed for them, or in the design of a machine in which they are expected to be used.

Other characteristics of synthetic lubricants distinguishing them from more conventional petroleum materials are their differences in density, thermal stability, oxidation resistance, hydrolysis resistance, and rust preventive qualities. Many of these characteristics can, and usually do, result in behavior of the lubricant in an entirely different fashion than previous experience with petroleum would indicate. For instance, the majority of the synthetic lubricants, even though they possess low volatility and generally good ability to wet metal surfaces, show

CLASS	VOLATILITY	VISCOSITY TEMPERATURE CHARACTERISTICS	OXIDATION RESISTANCE	LUBRICITY	THERMAL STABILITY	HYDROLYSIS RESISTANCE	FIRE RESISTANCE	SOLVENT EFFECTS ON PAINTS, RUBBER, ETC.	RESISTANT MATERIALS AVAILABLE?	SOLUBILITY IN PETROLEUM AND SYNTHETICS	IMPROVEMENT ADDITIVE COMPATIBILITY	PRICE RANGE IN $ PER GALLON
Dibasic Acid Esters	Generally lower than petroleum oils	G to E	F to G	F to G	F to G	F to G	P to F	Pronounced effects	Some	G to E	G	5 to 10
Phosphate Esters	Generally lower than petroleum oils	F to G	G to E	G to E	P to F	P to G	G to E	Pronounced effects	Yes	G to E	G	4 to 12
Silicones	Much lower than petroleum oils	E	E	P to F	F to E	E	P to G	Generally small effect	Yes	P	P	30 to 40
Silicate Esters	Lower than petroleum oils	E	P to F	F	E	P to F	P to F	Some effects	Yes	F to G	F to G	10 to 12
Polyglycol ether Compounds	Approximately equal, some lower than petroleum oils	G to E	P to F	G	F to G	F to G	F to G	Pronounced effect on paint. Small effects on rubber	Some	F to G	G	2 to 6
Trifluoro vinyl chloride Polymers	Some lower, some higher than petroleum oils	VP	E	P to E	E	E	E	Practically none	Yes	VP	VP	180 to 225

★The following code is used to indicate the range of each property described herein.

E for Excellent F for Fair

G for Good P for Poor

VP for Very Poor

Table II General properties of some classes of synthetic lubricants. (For comparison, the average well-refined petroleum product would be rated Fair to Good for most of its properties. Exceptions are fire resistance, where most petroleum products would be marked Poor, and hydrolysis resistance where they would be Excellent.)

up rather poorly as compared to equivalent viscosity petroleum products in rust preventive quality. Many of them are readily improved in this regard through the use of conventional polar-type rust preventive additives. Certain other classes of synthetics are difficult to inhibit for this type of service. Here again it should be emphasized that the behavior of an analogous series of synthetics in many of these physical and chemical characteristics cannot be predicted so readily as is the case with petroleum hydrocarbons.

We shall now review some of the principal classes of synthetics with brief emphasis on their various physical and chemical characteristics as compared with petroleum lubricants. Table II is a rather general chart summarizing most of the properties of each class. Table III shows some of the general uses to which each class has been put. It should be clearly emphasized at this point that the general descriptive language used to characterize the functional properties of these lubricants should not be interpreted as endorsing or condemning any one family of materials. Wide variations in some properties exist within each class, and in some cases the properties of a particular member, or even of an entire sub-group, may not agree with the generalized terms necessary in tabulations of this type. It has been stated earlier that almost any one of the classes of synthetics, or for that matter, almost any one individual member of any one class of synthetics, is sufficient subject matter for an extensive research evaluation. A fairly complete bibliography indexed by chemical type is included with this paper.

MONOBASIC ACID ESTERS. As pointed out by Glavis and Stringer,[1] the monoesters which combine any reasonable number of advantages of many of the other synthetics are rather limited in number. Some have relatively good lubricating properties and may be useful for these purposes. On the other hand, many of them described by the reference above show such weaknesses as relatively high wear, high volatility and fairly high melting points. Those which do not exhibit the above weaknesses are not outstanding in low temperature characteristics, or seem to be susceptible to oxidative breakdown. From the standpoint of synthetic lubricants as they are now conceived, and for the purposes which were outlined earlier in this paper, they probably do not constitute a very important class of materials. Their widely varying characteristics make it difficult to draw general conclusions, and for these reasons they have not been included in Tables II and III.

DIBASIC ACID ESTERS. This family of synthetic lubricants represents one of the most promising types that have been explored to date. They are already finding fairly widespread usage as low volatility grease bases, synthetic turbine lubricants, low volatility instrument lubricants, and as components in many other synthetic lubricant formulations. Many members of the family are available from pe-

troleum hydrocarbon synthesis. Others are available from such sources as castor beans and animal tallow. As a general rule they are characterized by excellent viscosity-temperature properties, rather low volatilities, and low freezing points. Their lubricating characteristics from the physical standpoint are therefore quite good. Their chemical lubricating characteristics, of course, vary depending upon their particular structure, but in general they are as good as, or better than, equivalent petroleum hydrocarbons. They are high in chemical solvency and readily accept such additives as lubricity improvers, oxidation inhibitors, some rust inhibitors, and viscosity index improvers. They show a rather high solvency for most types of elastomers. Their thermal stability, while not the equivalent of pure, saturated hydrocarbons, is still excellent from a practical consideration. They are somewhat more stable to oxidation than a petroleum oil of comparable viscosity. They also have the happy facility of blending quite readily with many other classes of synthetics, thus enabling the compounder to enhance their properties. Their hydrolysis resistance is generally good, particularly in the higher molecular weight members of the family. Undoubtedly one of the most widely-used members of this family to date is di-2-ethylhexyl sebacate, which is also available as a commercial plasticizer. Many excellent papers on this class of synthetic are referenced in the bibliography.

PHOSPHATE ESTERS. Another important class of synthetics that have found some industrial use for the past 10 to 15 years, and which are finding increasing use today as synthetic lubricants, are the phosphate esters. Many new members of this family are coming into existence every year. For many years they have been widely used in relatively small proportions as lubricity additives in petroleum lubricants and some of the other synthetics. Tricresyl phosphate is a material widely known for these purposes. Many members of this interesting family possess sufficient chemical stability to enable their use as the principal component of a synthetic lubricant. Others may be somewhat overactive and are too eager to perform the function of a mild extreme-pressure material. A great many members of the phosphate ester class have excellent fire-resistant properties and almost all of them are better in this regard than equivalent petroleum oils. The oxidative stability of most phosphate esters is rather good, and the thermal stability, while good up to medium-high temperatures, suddenly reverses and they become rather poor materials for sustained high temperature usage, for instance, above 300F. Their hydrolytic stability ranges from poor to very good, depending on their structure and molecular weight. They have excellent chemical solvency properties resulting in rather ready admixture with other synthetics and with petroleum hydrocarbons. For these same reasons they are strong solvents for paints and many types of synthetic rubbers. On the other hand, a number of rubbers and plastic materials have been found to be compatible with these esters, for instance, butyl rubber, thiokol rubber, some silicone rubbers, nylon, Teflon, Polythene and others. There volatility is quite low, and in the same general order as the dibasic acid esters. While there are a number of very low viscosity members of this class, the viscosity-temperature characteristics of most of the members can be classified as medium-to-good; that is, they are the equivalent of the better petroleum products, but do not approach the viscosity-temperature characteristics of the best petroleum products on an equivalent viscosity basis. On an equivalent volatility basis they are generally superior to petroleum.

Class	Use
Dibasic Acid Esters	Instrument oils, low volatility grease bases, special hydraulic fluids, jet turbine lubricants.
Phosphate Esters	Fire resistant hydraulic fluids, low-volatility high-lubricity grease bases, lubricity additives in other synthetics, special low temperature lubricants.
Silicones	Condensation pump lubricant, low volatility grease base for lightly loaded bearings, damping fluids, devices requiring minimum viscosity change with temperature.
Silicate Esters	Heat transfer fluids, high temperature hydraulic fluids, low volatility—low viscosity grease bases. Components for low viscosity hydraulic fluids.
Polyglycol-ether Compounds	Synthetic engine oil, special hydraulic fluids, forming and drawing lubricants, low temperature grease bases, rubber tire bag lubrication, vacuum pump lubricants, component of other synthetic lubricant formulations.
Trifluoro vinyl chloride polymers	Non-flammable, extreme oxidation resistant lubricant for plant processes or devices handling reactive materials. Heat transfer fluid.

Table III General uses of synthetic lubricants.

SILICONE POLYMERS. Much has been written and much intensive development work has been done in this interesting class of synthetics. At least 2 or 3 large companies are actively working and producing in this field. While there are many members of the silicone lubricant family, the most common ones known today are the dimethyl silicone polymers and the methylphenyl silicone polymers. Unlike the previous synthetic family discussed, the silicones are polymeric materials and the various viscosity grades available are the result of increasing chain length in an otherwise similar molecule. They are thus characterized by being repeating structures with the same alkyl or aromatic radicals attached. Some of these materials have the best viscosity-temperature characteristics of any of the synthetics now generally known. They are available in complete viscosity ranges and their volatilities are exceptionally low in almost all cases when compared to other materials of equivalent viscosity. Their oxidation resistance characteristics are excellent from low to very high temperatures. The thermal stability, however, of the group with the best viscosity-temperature characteristics (the dimethyl silicones) is somewhat lacking at sustained high temperature and repeated medium-to-high temperature fluctuation has been known to cause further polymerization in some cases. Their chemical solvency properties are distinctly different from most other synthetic lubricants. They do not readily accept additives, and only the extremely low viscosity members are soluble in petroleum products or in other synthetics. This low chemical solvency accounts for their general freedom from attack on many plastic, rubber and paint-like materials. Sustained operation at elevated temperature with most synthetic rubbers results in a gradual hardening of the rubber, apparently due to a preferential extraction of the rubber plasticizer. Their hydrolysis resistance in neutral media is good. It would seem that at last we have located a general-purpose fam-

ily; but alas, we have forgotten their lubricity. While excellent lubricants from the standpoint of physical characteristics, that is, viscosity-temperature characteristics, etc., their chemical-lubricity characteristics are remarkably lacking except in very special instances. Gadsby's work[23] indicates that most silicone oils can be classified as poor chemical lubricants on ferrous metal applications. They show ability to perform comparatively as well as petroleum on many other metallic surfaces, most of which, however, are not in general use for bearings. Recent work in formulation and structural change indicates possible improvement in this regard.

A word might be in order at this point on the author's delineation between physical and chemical lubricity. It is felt that the light-to-medium load lubricity requirements of most functional systems is more likely to depend upon the viscosity and viscosity-temperature characteristics of the lubricant than anything else. The chemical polarity of the molecule may influence this to a degree, and if high rotative speeds are concerned, shear resistance may also be important. In high or occasionally high load applications, however, the chemical polarity and/or the extreme-pressure chemical properties of the lubricant, or the lack of any proclivities along this line, are likely to prove the important issue. Our remarks in these paragraphs on lubricity will be confined to the generalization indicated above.

SILICATE ESTERS. This interesting class of synthetics, though old from the standpoint of chemical history, is one of the newest to see application and intense research work for the purposes of lubrication. As early as 1846 an article appeared[27] describing one of the members of this family, but it is doubtful that at present over 20 to 30 members of the silicoorthoester family have seen any extensive research evaluation.

The silicate esters are compounds, ordinarily monomers, with a single atom of silicon to which are joined four alkyl or aryl hydrocarbon radicals through an oxygen bond. They are ordinarily produced through the reaction of silicon tetrachloride with the desired alcohol, or by reacting the proper alcohol with previously-prepared ethly silicate. Raw materials are fairly readily available for their manufacture, but considerable care must be exercised in their preparation to insure a high degree of purity, since some of their undesirable characteristics are highlighted by any impurities. The principal advantage of this class of synthetics is that of high thermal stability. With proper oxidation inhibitors, they have been demonstrated to operate satisfactorily for hours, and even days, at temperatures in the range of 400 to 500 F. Careful formulation work is ordinarily required, however, to maintain adequate control over other physical properties such as viscosity, etc., at these elevated temperatures. These synthetics are available in several different viscosities, depending upon chemical type, and almost all of the members so far suggested for synthetic lubricant work have been shown to have outstanding viscosity-temperature properties, viscosity indexes being in the 150 to 200 range. They are unusually low in volatility and unlike their closely-related cousins the silicones, they have fair but not outstanding lubricity properties. Again unlike the silicones, however, they readily accept additions of conventional lubricity-improving agents. In general, their chemical solvency properties are rather high, but some members are not readily compatible with other chemical solvents. Similarly, while they do not attack most plastics and synthetic rubbers, they are somewhat like the silicones in that they tend to harden these rubbers after extended contact at elevated temperatures. Their wide temperature range of usability from the standpoint of viscosity would seem to favor a more extensive use than has been seen for them to date, but extreme caution is being exercised by the research organizations working with these materials, due to a knowledge of their rather poor hydrolysis resistance. To a certain extent, the tendency of silicates to hydrolyze can be inhibited and likewise the hydrolysis products which they liberate are not particularly damaging or corrosive, but complex decomposition products are always a possibility. Their principal indicated usage for high temperature applications will probably tend to minimize this particular shortcoming. The oxidation stability of the silicates, while not very good, is easily improved at a rate unparalleled by most other classes of synthetics. Their rust preventive properties are not known to the writer, but all indications are that they would be somewhat poor as compared to petroleum, but reasonably easy to improve. Their industrial use so far has been limited to heat transfer fluids, and some rather widespread effort has been made to gain their acceptance as an all-temperature internal combustion engine coolant.

Spec. No.	Type Lubricant	Principal Use
MIL-G-3278	Grease—Low volatility	An ester-base low volatility, low-to-high-temperature ball bearing and general purpose aircraft lubricant.
MIL-G-7118	Grease E. P.	An ester-base extreme-pressure type grease for use in aircraft where load support requirements exceed capabilities of MIL-G-3278.
MIL-G-4343	Grease	A synthetic-base grease for lubrication of "O" rings and other components in pneumatic systems.
MIL-G-7421	Grease	An extreme low temperature ester-base grease for low torque on instruments and other equipment operating below −65°F.
MIL-L-6085a	Oil—Low volatility	An ester-type low-volatility oil for use in instruments, air turbines, etc., where low evaporation is essential.
MIL-L-6387	Oil—Hydraulic—Special	A specially compounded ester-base hydraulic fluid for alternator drives.
MIL-L-7808	Oil—Aircraft turbine	An ester-base low-volatility, high-temperature, general-purpose lubricant for jet turbines.

Table IV Military specifications on synthetic lubricants.

POLYGLYCOL ETHERS & RELATED COMPOUNDS. Many types of glycol and glycol derivative products have been suggested as synthetic lubricants. Probably the most distinctive family group, however, are the polyalkylene glycols and their derivatives described by J. M. Russ[33]. They are available in several series or types, the principal types being a water-soluble series and oil-soluble (or at least water-insoluble) series. They are available in a variety of viscosity and molecular weight grades. Although the viscosity-temperature properties of many of the members of this family are ap-

proximately equal to petroleum, there are specific family sub-groups which have viscosity-temperature properties far superior to petroleum with viscosity indexes in the range of 150. They are also characterized by having low pour points, low solvent and swelling effects on various types of natural and synthetic rubber, and a rather good resistance to sludge and varnish formation. From the standpoint of compatibility with other synthetics, their solvency properties are good, and many of the members of the family show good solubility in petroleum lubricants, particularly at elevated temperatures. The volatilities of these synthetics are not much lower than petroleum oils, but some members show advantages in this regard. The oxidation resistance of the polyalkylene glycols is somewhat lacking, but they seem to be fairly readily improved in this respect. They are said to have a unique property in that the decomposition or oxidation products are low molecular weight volatile compounds, or compounds having physical properties similar to the original product. Their resistance to mechanical shear is excellent. Two synthetics of this type are presently being marketed as automotive engine oils, where they have the advantage of viscosity properties bracketing several SAE numbers. This property is not considered by the writer to be of real significance in areas where low ground temperatures are not encountered or where wide fluctuations in temperature do not exist.

The water-soluble series are finding use in the rubber molding industries and in other places where a synthetic is desirable which is compatible with water and still not injurious to the elastomeric products. The water-soluble series, and to a certain extent the water-insoluble series, are finding increased usage in the automotive hydraulic brake fluid field when blended with various diluents.

The price of the polyalkylene glycols is in general rather low for synthetics and they appear to be available in good quantity. Since they represent a midway step between petroleum products and some of the more outstanding but more expensive synthetic lubricants, it is difficult to understand why they have not found more widespread acceptance in industry.

FLUORINATED & CHLORINATED COMPOUNDS. It is difficult to describe the fluorinated compounds as a family, since extensive chemical synthesis over the years has produced many types of organic compounds in which the hydrogen has been replaced by either fluorine or chlorine. Such a product, for instance, is carbon tetrachloride which, while used in rare cases for its extreme-pressure properties, is more commonly known as a non-flammable solvent of rather high toxicity. Probably the most representative materials in this class of compounds are the fluorinated or chlorinated hydrocarbons. Of the two, the older and most widely recognized are the chlorinated hydrocarbons. Materials such as the chlorinated diphenyl compounds have found limited use as synthetic industrial lubricants for a number of years. These and many other related materials have also been used as extreme-pressure additives to petroleum products, since a rather general characteristic of chlorine and fluorine in the molecule is to produce a high degree of chemical lubricity from the anti-welding or extreme pressure standpoint. This typical high activity of the halogens is probably the principal problem, however, that deters their increased usage as synthetic lubricants. The halogen atoms do not actively affect the lubrication properties to a large degree while still a part of the molecule. The problem has always been to produce a halogenated molecule which would exercise prudence in its desire to fraternize with other materials when pressed for action. The liberation of extensive amounts of halogens from their parent molecule can, of course, result in the formation of highly corrosive or toxic end products.

In recent years a great deal of emphasis has been placed on the fluorinated hydrocarbons. Several years ago an article describing a new non-inflammable fluorinated engine oil appeared in a British newspaper. The rather eager professor who released the news article on this material has suggested that it will be practically everlasting as a crankcase lubricant provided the cars have good oil filters and the lubrication system does not leak. This flamboyant optimism has unfortunately been rather characteristic of the less conservative proponents of these materials. That they have a high degree of chemical stability, especially when compared with many of the chlorinated hydrocarbons, is rather generally known. It is equally well known that they have a high degree of non-flammability. This latter characteristic is responsible for their use in the industrial processing of many highly reactive materials such as hydrogen peroxide. On the other hand, the most stable ones show a complete lack of any desire to get along with any other lubricants, synthetic or natural. Likewise they are not particularly effective lubricants on some metal surfaces. Those with good low temperature properties have quite often rather high volatility at elevated temperatures, as compared to petroleum lubricants, and in general the fluocarbons can be said to have poorer viscosity-temperature characteristics and narrower liquid ranges than equivalent hydrocarbon compounds. Certainly this class of materials, especially since many possible members have yet to be tried, can look forward to an extremely useful life in many specialized places in industry. It is almost equally probably, however, that their high initial cost, relative difficulty of preparation, high weight, and other properties described above, will not permit them to find widespread usage in the reasonably foreseeable future. With the intense research that is now going on in this class of synthetics, however, the author realizes that this prediction can suddenly become completely wrong.

TOXICOLOGY. In the review of the different classes of materials which we have briefly covered, it should be noted that the subject of toxicology was raised only in those instances where a toxic condition was known to exist. The individual family members of every class of synthetic must be regarded as entirely separate chemical materials from the standpoint of toxicology. The vast amount of experience which has been accumulated in the handling and use of petroleum products has taught us the types of hydrocarbons which are most toxic. Such a background of experience is not available for most of the synthetic lubricants, and for that reason this property should be considered in most instances before a choice is made. Data on specific synthetic lubricants and their possible toxic effects is rapidly becoming available through government and private

research agencies.

MILITARY USES. One of the important questions not covered in our previous discussion was the viewpoint of the military services on synthetic lubricants. All of the military services, and particularly the Air Force and Bureau of Aeronautics, have been very active in promoting and sponsoring research and development work in this field since the start of the last war. This is to be expected, since as outlined earlier, many of their operational requirements bring about the need for certain of the lubricant characteristics in which the synthetics excel. As a result of this, there are now at least three Military Specification oils and four Military Specification greases which are almost completely synthetic in formulation. Table IV shows these Specification greases and oils and their principal intended uses. Most of them to date are composed principally of dibasic acid esters, but active research has been carried on in other fields by the Military.

An excellent paper[13] on the subject of synthetic turbo-prop lubricants was presented by Capt. L. D. Christensen, of Wright Air Development Center, at the ASLE 7th Annual Meeting. Capt. Christensen indicated that the Air Force's principal concern, in the case of a turbo-prop synthetic lubricant, has been much the same as their reasons for development of the other synthetic lubricants which they and the Bureau of Aeronautics have specified. In almost all cases, the fundamental requirement has been to obtain low volatility at elevated temperatures, low viscosity at low temperatures, and good viscosity-temperature properties. Other lubricant characteristics, although important, were generally secondary with these basic requirements. It can be said that the Military Forces apparently regard the synthetic lubricant field with a great deal of promise in view of their current experience.

SUMMARY. Industry is seeing a gradual introduction of many of the synthetic lubricants discussed above. Fairly large quantities of phosphate esters are finding their way into fire-resistant hydraulic fluids for industry, such as in die casting machines. Formulations involving water and water-soluble polyalkylene glycols are seeing service in this same field. The chlorinated bi-phenyls have seen limited service in this field for a number of years. Greases made from the dibasic acid esters and other low volatility synthetics are finding their way into the hot running bearings of many industrial machines. These are but a few of the many uses to which synthetics are now being put in good quantity, and it is certain that the years to come will find increasing replacement of petroleum by synthetic lubricants in many specialized industrial and military fields.

Summing up all of the properties that were outlined for the various classes of synthetics, it should be noted that while each class of synthetic exceeds petroleum products in one or more of its properties as related to current usage, none of them so far revealed are as good in all of the properties as the petroleum hydrocarbons. Undoubtedly a large part of the responsibility for this success of the petroleum hydrocarbons is the fact that industry has been more or less designed around them, but this is no less a good reason for exercising sound engineering judgment in the selection between a petroleum lubricant or a synthetic lubricant for any particular job. The synthetics are certainly here to stay, but let us not deter their progress by improper selection or use.

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Lube Lines

ASLE MEMBER INTEREST SURVEY (submitted by T. G. Roehner, Socony-Vacuum Laboratories, Chairman of the ASLE General Technical Committee). There are now eight ASLE Technical Committees. The eighth, namely, Technical Committee on the Principles & Practices of Economic Lubrication, has completed its organization. The activities of the following eight Technical Committees are guided by the General Technical Committees: (1) Fluids for Metal Working, (2) Physical Properties of Lubricants, (3) Bearings & Bearing Lubrication, (4) Lubrication Equipment, (5) Lubrication Fundamentals, (6) Hydraulics & Hydraulic Machinery, (7) Lubrication Reclamation & Disposal, (8) Principles & Practices of Economic Lubrication. The membership of these Technical Committees is more than seventy.

Last year it was agreed that a survey should be conducted to determine where the interests of the entire ASLE membership were concentrated. That information would be used to guide the programs of the respective Technical Committees and also the selection of papers to be presented at the Annual Meethings. A questionnaire was formulated with the very able assistance of ASLE President W. E. Campbell. Over 2100 questionnaires were mailed from the Chicago headquarters — 951 replies were received. The following is a progress report on the data extracted from those replies:

(1) Type of work in field of lubrication occupying minor or major part of effort:

	% Major	% Minor
Research & Development	24.15	23.95
Machine Design	5.20	14.02
Machine Maintenance	18.37	19.86
Sales & Technical Sales	41.14	8.91
Education	6.10	27.84
Other	5.04	5.42

(2) General field in which company is engaged to a significant extent: Manufacturing 65.87%, Transportation 16.34%, Military & Government Service 5.27%, Education 4.96%, Mining 4.81%, Other 2.75%.

(3) Components or materials representing strongest present personal interest: Petroleum Lubricants 17.48%, Greases 13.52%, Extreme Temperature Lubricants 10.59%, Hydraulic Oils 10.19%, Additives, 10.05%, metal Processing Lubricants 9.91%, Lubricant Application Equipment 7.53%, Synthetic Lubricants 6.34%, Solid Lubricants 6.29%, Instrument Lubricants 3.54%, Machine Components 2.73%, Other 1.83%.

(4) Subjects which represent strongest present personal interest: Lubricant Application 27.39%, Lubricant Evaluation 21.12 %, Lubricant Development 17.49%, Lubricant Specification 15.64%, Basic Research 7.13%, Lubricant Reclamation 6.82%, Lubricant Disposal 3.86%, Other .55%.

(5) Services which it is felt can be improved: Section Meeting 31.76%, Lubrication Engineering Magazine 29.02%, Annual Meeting 17.65%, Education Committee Activities 10.59%, Advice from General Technical Committee 6.27%, Other 4.71%.

(6) New services which Society should initiate: (187 comments were received and will be summarized in a final report.)

The fact that 46-1/2% of the returned questionnaires contained comments and/or suggestions indicates a healthy membership interest in the operation of our Society. Although it may take considerable time, every comment and suggestion made will be carefully appraised and considered in planning programs and the operation of our Society. Further information on benefits derived from this survey will be forthcoming at a future date.

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A STUDY OF THE ROLE OF THE CUTTING FLUID IN MACHINING OPERATIONS*

by S. J. Beaubien & A. G. Cattaneo
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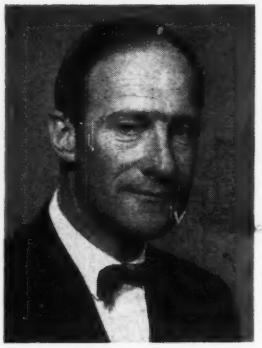

ABSTRACT: Cutting fluids have been studied with the object of understanding the mechanisms which link fluid properties and metal cutting performance. Performance was measured in terms of tool life, surface finish and tool forces. It was found that the most important properties were viscosity, wetting, heat capacity and chemical activity. Different degrees of functioning of these properites may be required, depending on the mechanics of the operation and the results desired.

The establishment of a scientific basis for the general field of metal cutting was slow in developing, but the last 10 to 15 years have seen an accelerated study in this field. Increasing advances are being made in geometry and energy considerations, and in metallurgical studies relating to metal cutting. However the existing knowledge of the role of the cutting fluid appears to be of a highly empirical nature. The work of this paper attempts to establish order to the relationships between cutting fluids and metal cutting performance.

The approach is somewhat difficult since, on the one hand, every cutting fluid has a number of properties which affect cutting processes and each fluid will not only differ in nearly every property from every other fluid, but also in the relative effectiveness of the various properties. On the other hand, from the mechanical viewpoint, the results with which the metal working engineer is concerned in practice, for example tool life or surface finish, are the end products of mechanisms which may be entirely different in different operations, or even under different conditions in the same operation. Thus, the knowledge of the effect of a particular change in fluid on a specific result of a particular operation is of little general use, and it appeared highly desirable to attempt a correlation between the individual properties of fluids as such, as we know them from a general background in lubrication and related fields, with the specific mechanism or mechanisms which lead to the end result observed in practice.

We have certainly not reached this goal by any means, and we have not even approached it to the extent which we would like for this initial presentation. Thus we can discuss only a limited number of metal working operations, and only a limited number of the possible variations in fluid properties, but we hope that the specific data and generally applicable trends, obtained by this approach, will contribute something to the understanding of the role of the fluid.

PROPERTIES OF CUTTING FLUIDS. To various degrees, any fluid applied to a machining operation will perform the following actions: flow to the area of the cutting action, wet the metal surfaces, remove heat, and modify the friction between surfaces with relative motion. Each one of these actions represent fluid properties which depend on a number of basic physical characteristics of the fluid. Since the same physical characteristic may affect several of these properties, and moreover physical characteristics as well as some of these actions may be interrelated also, these fluid properties are by no means independent. It is therefore not possible when choosing fluids for experimentation to change one of the properties without affecting the others also. This must be kept in mind in the interpretation of test results on different fluids, even if the controlled change is large compared to changes in other properties.

The first property, flowing to the area of the cutting action, will depend largely on the viscosity of the fluid. The wetting property will determine the degree to which the fluid directly contacts metal surfaces, particularly under adverse conditions. Inherently then, cooling will under such conditions also depend on the wetting property. In the absence of sufficient flow and wetting, a relocation of the coolant jets to mechanically bring the fluid to the critical tool areas can sometimes effect a significant increase in tool life.[1] Cooling, in the sense of heat removal, depends on the specific heat of the fluid, and the boiling temperature and heat of evaporation may also be important.

In discussing the reduction of friction it is necessary to realize that practically all machining operations produce conditions which preclude thick film lubrication. Under the resulting boundary conditions viscosity is a minor factor, and oiliness a large one. Under extreme conditions, when even this regime can no longer carry the load and seizure, i.e., welding, would result, E.P. agents can be used which, according to the best available theories, react with the metal surfaces to form an easily sheared surface layer. The effect thus also is one of reducing friction, but while ordinary boundary lubrication interposes some kind of thin film between the rubbing surfaces and thus protects the surfaces against attrition, E.P. agents by their very action, which is usually called corrosive, destroy the metal surface.

These appear to be the major fluid properties of significance in metal cutting. It is obvious that in an actual cutting operation they are not always readily distinguished. If, for example, in a particular operation a change in fluid produces a lower tool point temperature, then an improvement in any one of the properties might have been responsible. In such a case an analysis of the cutting mechanism,

*Paper presented at the ASLE Northern California Section Meeting, Jan. 14, 1954.

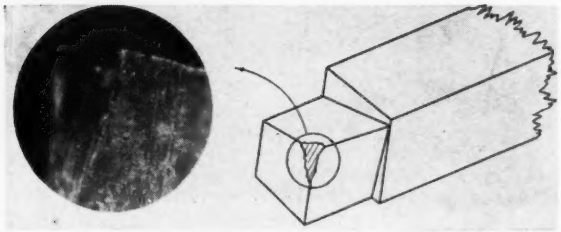

Fig. 1 Tool failure by sudden shearing of hot point under heavy duty conditions.

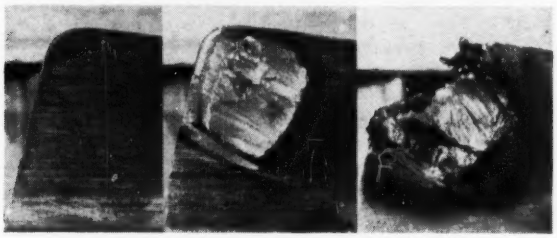

Fig. 2. Progressive failure of lathe tool operation under heavy duty conditions; (left) new lathe tool, (center) typical crater on rake surface, (right) disintegrated point of failed tool.

or the fluid properties, or both, will indicate the property responsible. For this purpose the main properties of the two common cutting fluids, water and mineral oil, may here be described.

Water is an excellent coolant by virtue of high specific heat (which is reduced by practically any type of additive), low boiling point and high heat of evaporation. Its viscosity is very low, and thus it flows readily to the desired point. It wets clean steel well, and its wetting properties towards steels which are not clean are readily enhanced by the addition of soaps. It is exceedingly poor as a lubricant under boundary conditions, and although this property can be improved by additives, in current practice water is most often combined with mineral oil as a so-called soluble oil.

Mineral oils cover a wide range of viscosities generally higher than that of water. It is therefore much more difficult to bring them to flow to the scene of the cutting action. They wet steel as well as water when it is clean, and much better when it is not. Their cooling property is very inferior to that of water. Their ability to reduce friction under boundary conditions is outstanding, and can be further enhanced by the addition of fatty acids or other oil soluble compounds containing polar groups. With E.P. agents, usually oil soluble compounds containing chlorine or sulfur, the severity of the conditions under which oils maintain low friction can be further extended.

In the following analysis and experimental work we have largely used air, water alone, water with a wetting agent, mineral oils and mineral oils containing an E.P. agent. A few data obtained with soluble oils are included but it will be seen that they have hybrid properties and do not lend themselves well to the analysis which is our purpose here. For the same reason many other possible variations of cutting fluids are not included, however useful they may be in practice, where secondary properties, such as rusting, foaming, etc., take their rightful place beside the cutting properties.

EFFECT OF FLUID PROPERTIES ON

Fig. 3 Progressive failure of drill by overheating of chisel point; (left) new drill, (center) 60 holes, (right) final failure at 86 holes.

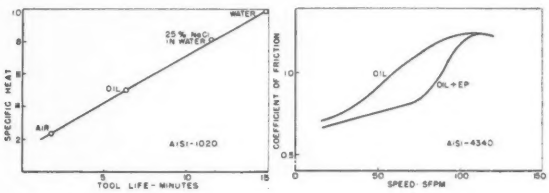

Fig. 4 (left) Effect of cooling on heat-limited tool-life. Lathe Turning: speed 175 SFPM, depth 0.150", feed 0.035, tool 8-14-6-6-6-15-0.050" HSS.

Fig. 5 (right) Effect of extreme pressure agents on the coefficient of friction between chip and tool. Lathe Turning: depth 0.150", feed 0.0057"/rev., tool 0-10-6-6-6-0-0 HSS.

TOOL LIFE. A. Tool Life Limited by Excess Heat. First will be considered a tool failure caused by the sudden shearing away of the tool point. This is usually preceded by the reduction of some critical tool cross section, such as cratering in a lathe tool, which weakens the tool structurally and raises the point temperature by creating a heat dam, Figs. 1 & 2. Alternately, the same type of failure may occur after gradual tool wear has rearranged the forces so that excessive heat is generated at the tool point, melting the tool; some cases of chisel point failures in drills follow this pattern, Fig. 3. In all cases this failure is characterized by excessive heat at the tool point.

In this type of failure cooling will accomplish large improvements in tool life. When various fluids are compared the dominant effect of cooling is evident, Fig. 4. Changes in the viscosity of the oil had no effect.

However, in some metal cutting processes such as a severe drilling operation, even for conditions where this type of tool failure controls tool life, coolants may not be effective if they cannot reach the tool point in sufficient volume to function. Generally equivalent results were obtained when water or mineral oil were applied externally in a severe drilling operation. In the same operation, the addition of a wetting agent to water increased the drill life threefold. Even more effective was the use of a hollow drill to deliver water directly to the drill point. A 15 to 20 fold increase in drill life was obtained in this way.

It would appear from Fig. 4 and the experiment just described that variations in the friction reducing property of the fluid have no effect on heat limited tool life. However, if E. P. agents are added to a mineral oil, this kind of tool life is increased a small but significant amount. It is of interest to this discussion to trace the mechanism which produces this result. When the coefficient of friction

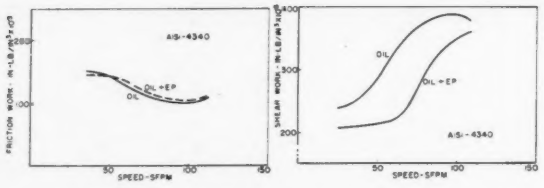

Fig. 6 (left) Effect of extreme pressure agents on friction work at tool surface. Lathe Turning: depth 0.150", feed 0.0057"/rev., tool 0-10-6-6-6-0-0 HSS.

Fig. 7 (right) Effect of extreme pressure agents on shear work on chip. Lathe Turning: depth 0.150", feed 0.0057"/rev., tool 0-10-6-6-6-0-0 HSS.

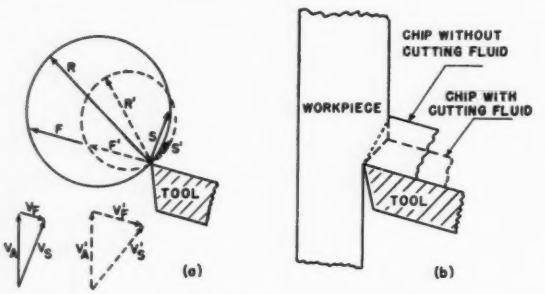

Fig. 8 Influence of extreme pressure cutting fluids on chip geometry; (a) Force and velocity diagrams showing how reduction in friction by E. P. cutting fluids (dotted lines) reduces cutting force and increases tool chip velocity, (b) Reduction of chip deformation by application of E.P. cutting fluid.

between the chip and the tool is computed from dynamometer data for an uncompounded oil and for one containing an E.P. agent, the results are as shown in Fig. 5. It might at first appear that the reduced coefficient of friction would mean less heat generated at the chip and tool interface. However, when the friction work and the shear work are computed it is seen that the reduction in the coefficient of friction by the use of the E.P. agent has only a negligible effect on friction work and that almost the entire advantage appears as a reduction in shear work, Figs. 6 & 7.

Expressed simply, the events which bring about the above results can be described with the help of the diagram in Fig. 8. Referring to the circle diagram, when the E.P. agent is added to oil, the friction force is markedly reduced and consequently the chip shears at a larger shear angle. The effect of this change in shear angle on chip velocity is shown in the velocity diagrams. A small change in the direction of V_S (the velocity of the chip with respect to the work) results in nearly doubling the magnitude of V_F (the velocity of the chip with respect to the tool). Since F (the friction force, parallel to the tool face) was about halved by the E.P. oil, the product FV_F (friction work) did not change appreciably. The shear velocity however, did not change much with an E.P. oil and the shear work product, SV_S, reflects the appreciable change in the shear force, S.

The result of reduced shear work is a cooler tool point; however, there is probably less advantage in this respect than if friction work had been reduced, because of the concentration of energy at the tool-chip interface for the latter case. Even so, this mechanism results in increased tool life for those applications where the tool normally fails from ex-

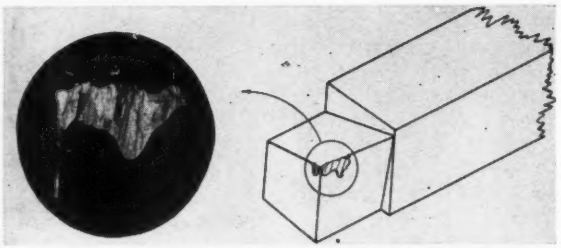

Fig. 9 Tool failure by gradual wearing of flank surface.

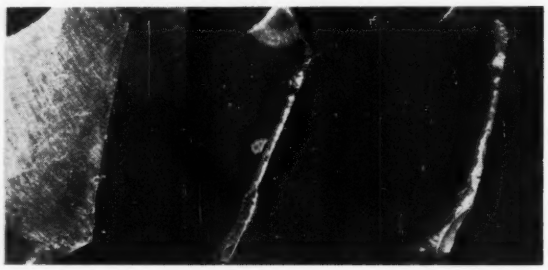

Fig. 10 Progressive failure of drill by gradual wear of clearance face; (left) new drill, (center) 90 holes, (right) final failure at 100 holes.

cess heat; however, it does not compare in this respect to adequate external cooling. For example, under conditions giving a 60 minute tool life in lathe turning of AISI 4340 steel with water, oil had about a 10 minute life and oil + E.P. agents had about a 15 minute life.

B. Tool Life Limited by Wear. A second kind of tool failure is one in which the tool gradually wears to a degree such that dimensional or surface finish tolerances cannot be met, or tool load is excessive, or the limit for economic salvaging of the tool is reached. In all cases this failure results from a gradual change in tool dimensions, usually with no sudden change in the quality of the product produced, Figs. 9 & 10.

Under these conditions reduction of friction appears to be the most important property of the fluid since oil is far superior to water, Fig. 11. The addition of an E.P. agent has usually only a small effect, sometimes beneficial, but more often it produces faster wear, attributable to the corrosive action of the additive.

One might expect from Fig. 11 that oil in water emulsions would give results falling between each of the components. However, at water dilutions and with oil viscosities commonly used, the results are not significantly different from water alone. An exception to this occurs with the newer heavy duty emulsions containing E.P. agents; with these fluids the performance may approach that obtained with E.P. agents in oil.

With wear limited tool life, viscosity is important. In a drilling operation for example, oil viscosity can modify tool life by about a factor of three; this is true whether the oil is used neat or in oil and water emulsions, Fig. 12. Since the emulsifying agent always present in water emulsions also acts as a wetting agent, the data in this figure show the combined effect of viscosity and wetting.

For lathe cutting at moderate metal removal rates where wear controls failure, there is also an advantage for increasing viscosity, but mechanical factors may limit the use of this fact. When a light

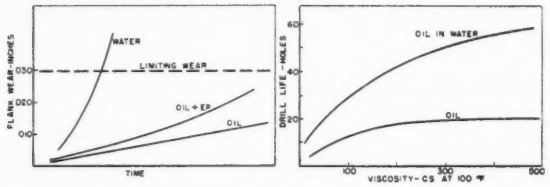

Fig. 11 (left) Effect of lubrication on tool wear. Lathe Turning: speed 130 SFPM, depth 0.075", feed 0.020"/rev., tool 0-10-6-6-6-0-0 HSS, AISI 1020 steel.

Fig. 12 (right) Effect of viscosity on drill life. ⅜" drill, speed 1240 rpm., feed 0.006"/rev., depth 1", AISI 4340 steel.

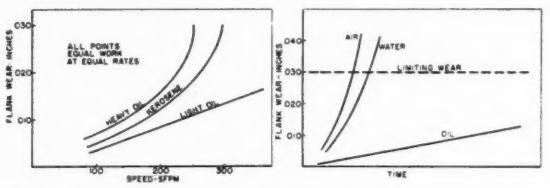

Fig. 13 (left) Effect of viscosity on tool wear. Lathe Turning: 20 in³ of metal cut at 2.35 in³/min., depth 0.075", tool 0-10-6-6-6-0-0 HSS, AISI 1020 steel.

Fig. 14 (right) Effect of cooling on tool wear. Lathe Turning: speed 130 SFPM, depth 0.075", feed 0.020"/rev., tool 0-10-6-6-6-0-0 HSS, AISI 1020 steel.

mineral oil (26 cs at 100 F.) was compared to a kerosene fraction and to a heavier oil (216 cs at 100 F.) the light mineral oil was consistently best and showed the greatest advantage at high speed, Fig. 13. The results undoubtedly depend upon test conditions, and will vary with tooling and procedure changes. Apparently in this work the heavy oil was too viscous to flow adequately to critical wear areas, especially at high speed. Both kerosene and light oil gave tool protection but since the more viscous material was best, we conclude that viscosity is important for this kind of tool life, probably through a reduction of the metal to metal contact, i.e., friction.

Cooling has no significant effect on this type of tool failure, i.e., it does not appreciably affect the wear rate of a moderately loaded tool, Fig. 14.

C. Tool Life Limited by Welding. A third kind of tool failure results from welding of the workpiece material to the tool. In many instances this process may be desired to some degree, as for example the built up edge on a lathe tool. In drilling or reaming, however pick-up on the tool may seriously limit its further use, Fig. 15.

E.P. agents in oil have a pronounced effect on this mechanism, often increasing tool life by as much as 10 or 20 fold. Cooling with water alone has a lesser but appreciable effect in some applications, and oil alone has no significant effect.

At this point we may also consider the effects of E.P. agents on tools which fail by the sequence of wear and welding. Severe drilling, at about four diameters deep in a steel like annealed AISI 4340, provides an interesting example. Failure occurs through the following chain of events: wear occurs on the cutting edge near the periphery (corner), where the surface speed is highest; as the drill advances into the resulting tapering hole the drill margin clearance is reduced to zero and the friction in this highly loaded area causes welding of the drill margin to the workpiece. For this application,

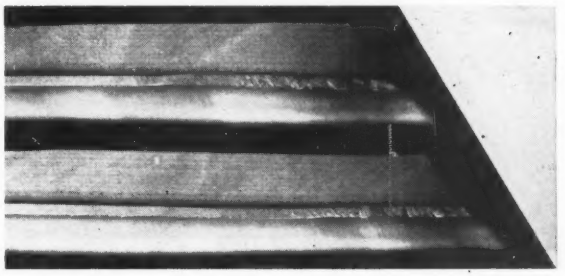

Fig. 15 Developed drill surface, showing typical failure by welding (pick-up) on the drill margins.

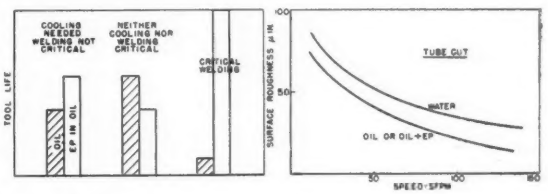

Fig. 16 (left) Typical effects of extreme pressure agents on tool life limited by cooling, wear and welding; various operations.

Fig. 17 (right) Effect of lubrication on surface finish for single contact cutting on the end of a tube. AISI 4130 annealed steel, 0.0028" feed, tool 0-10-6-6-6-0-0 HSS.

when oil alone was compared with E.P. agents in oil it was found that corner wear, the precursory mechanism, was less for oil alone than for E.P. agents in oil. However the latter fluid is so much better able to tolerate the high load resulting from wear that ultimate tool failure from seizure was postponed and drill life prolonged greatly. The overall effects of E.P. agents on the three kinds of tool life discussed are shown in Fig. 16.

EFFECT OF FLUID PROPERTIES ON SURFACE FINISH. Somewhat less clearly defined, but nevertheless exhibiting distinct differences, are the processes governing the relationships between fluid properties and surface finish.

A. Single Contact Cutting. Largely of academic interest, but seen to a limited extent with some tools, is the surface finish produced by a single contact of the tool. In the laboratory this is accomplished by cutting a continuous chip on the end of a tube; in practice, a roughing broach is an example of the process.

In this type of application cooling seems to have a slight negative effect on surface finish. For some operating conditions, dry, mineral oil, and water, were found to give slightly increasing roughness in that order. Apparently the chip is sheared more cleanly from the workpiece when the chip and tool are at higher temperatures. When the surface is reworked by the tool this small advantage is lost.

Neither oil alone, nor E.P. agents in oil had any significant effect, Fig. 17. The effect of oil viscosity was not evaluated.

B. Multiple Contact Cutting. In most practical applications the major cutting edge of the tool generates an endless transient surface, the chip, which is discarded. The finished workpiece surface is formed by successive passes of the tool point as it is fed across the work. In the simplest terms most practical metal cutting shears the chip from the

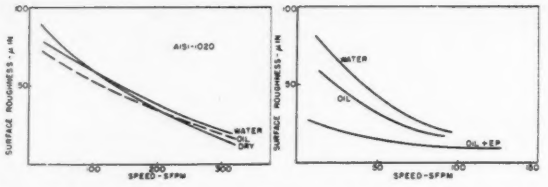

Fig. 18 (left) Effect of cooling and lubrication on surface finish for multiple contact cutting. Feed 0.0028", depth 0.025", tool 8-14-6-6-6-15-0.050" HSS.

Fig. 19 (right) Comparison between maximum benefits from oil and typical results from extreme pressure agents in lathe turning. Feed 0.0028"/rev., depth 0.150", AISI 4340 annealed steel, tool 8-14-6-6-6-15-0.050" HSS.

work, and then smooths and burnishes the surface by subsequent passes of the tool.

The effect of cooling is usually negligible. In lathe cutting for example, cutting dry, with water, or with mineral oil gave about the same finish (± 10μ in) throughout a range of speeds, and with finishes ranging from 20 to 100μ in., Fig. 18. The question of changed lubricity does not appear to enter here since the coefficient of friction is the same (± 0.05 units) for each fluid at any given speed in this application.

Oil alone has little effect on surface finish. However, E.P. agents in oil are quite effective for improving finish in the reworked surface processes. The maximum potential of oil under favorable conditions is compared to typical results from E.P. agents in oil in Fig. 19.

Although much work of merit has been done regarding the control of the mobility of the built up edge with E.P. agents, and the subsequent effect on surface finish, these data together with the negative effect found in single contact cutting, suggest that E.P. agents are most useful when they enhance the reworking and burnishing action of the tool. They probably function by preventing surface irregularities and portions of built up edge, which have escaped onto the workpiece, from rewelding to the tool and being plucked from the surface.

Since the primary effect of wetting agents is increased cooling, and since cooling alone has little direct effect on surface finish in the usual applications, normally wetting agents do not influence surface finish. Exceptions are found in applications with restricted cooling and which cannot tolerate tool pick-up without loss of surface quality.

Drilling and boring are common examples of these applications, while a wide plunge cut on a lathe represents a less common but just as susceptible a process. The latter cut is usually inadequately cooled because the fluid is diverted from the tool point by the chip and the dam created by both sides of the cut.

C. Thread Cutting. No general physical differences between the conditions for thread cutting with dies and those for general multiple contact cutting are apparent, except that the small diameter thread (½ inch) studied here, together with the use of a four chaser die permitted only a short time interval between tool contacts at reasonable surface speeds.

Nevertheless, in thread cutting with dies, cooling has a decided beneficial effect on surface finish, Fig. 20, while it has none in multiple contact cutting. This discrepancy is so pronounced that we conclude that this operation is probably particularly sensitive

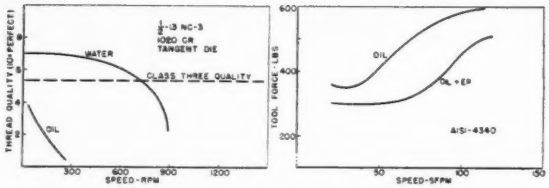

Fig. 20 (left) Effect of cooling on thread finish.

Fig. 21 (right) Effect of extreme pressure agents on tool force. Lathe Cutting: feed 0.0057"/rev., depth 0.150", tool 0-10-6-6-6-0-0 HSS.

to pick-up, and it is the reduction of pick-up through cooling that accounts for excellent thread finish. Of course E.P. agents also produce a fine finish in this operation.

EFFECT OF FLUID PROPERTIES ON TOOL FORCES. Tool forces were measured on tool dynamometers. These forces were utilized in two ways; first as a direct measure of tool and machine loading, and second, through the mathematics of metal cutting as developed by Merchant, an analysis of the forces provided a measure of some of the fundamental elements of metal cutting such as shearing work, friction work and coefficient of friction.

No significant effect of cooling on the magnitude of the resultant tool force has been found. One might at first think that cutting dry (as compared to cutting with water) would raise the temperature sufficiently to lower the shear strength of the metal in the shear plane. If the shear strength is calculated from dynamometer and cutting ratio data, it is found that dry, water, and mineral oil, yield identical curves when shear strength is plotted against speed and thus the fluid has no effect on this result. This of course agrees with the observed fact that the corresponding resultant forces are approximately equal.

As may be gathered from this discussion of friction and shear work, oil alone has only a little effect on tool forces. However, E.P. agents in oil reduce the total tool load by as much as 40%, Fig. 21. In many cases this will not be of particular interest to the user since power cost is usually not important and machines are designed to tolerate high loads. However, some machines, such as drill presses, are frequently torque limited, and the reduction in torque possible with E.P. agents (about 30%) permits a significant increase in machine productivity.

The effect of viscosity on tool load is not large, and generally negligible. In drilling with four oils ranging from 26cs at 100 F., to 500 cs at 100 F., no differences in torque were found. With oil in water emulsions in the same test, the high viscosity oil gave a 10 to 20% reduction in torque over the same viscosity range. For lathe turning, no significant difference in resultant tool force was found for either oil in water emulsions or neat oils with varying oil viscosities.

CONCLUSION. It will be obvious that the relationships which we have been able to show between the major cutting fluid properties and some of the most important performance criteria in common forms of metal cutting, deserve further study in many cases, and their application to a wider range of fluids as well as machining operations would be

useful. It is our belief that from such work considerable benefits may be expected, since it emphasizes as well as evaluates the role of the cutting fluid in sufficient detail to permit purposeful development.

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[1]W. E. Lauterbach: Influence of Point of Application of Cutting Oil on Tool Life. Lub. Engrg., June 1952. From a study at Armour Research Foundation sponsored by Shell Oil Co.

ACKNOWLEDGMENT: Among our collaborators L. P. Richardson in particular deserves recognition of his contributions.

Section News

A Speakers' Bureau has been established to provide a source of speakers on various technical subjects, and to aid the various Sections and the National Program Committee in planning future ASLE activities. Any Section wishing to use the Speakers' Bureau should contact Chairman D. W. Sawyer, Aluminum Co. of America, P. O. Box 772, New Kensington, Pa., indicating the particular field or fields of interest. Mr. Sawyer will furnish the names of the speakers available, with further negotiations to be made between the local Section and the respective speakers.

Baltimore January meeting — J. P. Critchlow, Gulf Oil Corp., presented a paper entitled A Discussion of the Characteristics & Uses of Extreme Pressure Lubricants.

February meeting — M. Levinsohn, of the Bearings Section-Mechanical Lab., U. S. Naval Engineering Experiment Station, spoke on the subject Problems Connected with High-Load, High-Speed Journal Bearing Design in Naval Vessels, and their Practical Applications to Machinery.

March meeting — R. Q. Sharpe, Socony-Vacuum Oil Co., presented a paper entitled Maintenance of Industrial Hydraulic Systems.

April meeting — M. E. Merchant (former ASLE President), Cincinnati Milling Machine Co., will speak on the subject Metal Cutting and Cutting Fluids — Latest Developments in These Fields. (Submitted by W. W. Witmer, Sec'y Treas.)

Cincinnati January meeting—W. E. Campbell (ASLE President), Brush Labs. Co., Div. of Clevite Corp., presented a paper entitled The Current Status of Fretting Wear.

February meeting — W. H. Wetmore, General Electric Co., spoke on the subject Jet Engine Lubrication Systems, in which system and lubricant requirements for the proper functioning of jet engines was described. (Submitted by R. L. Peters, Sec'y-Treas.)

Connecticut January meeting — T. W. Langer, Union Carbide & Chemicals Corp., presented a paper entitled Some Industrial Experiences with Synthetic Lubricants. After briefly comparing the poly-alkalene glycol derivatives, diesters, silicones, and fluorcarbons, actual applications of poly-glyco derivatives as lubricants were discussed. Tests made under extreme service conditions, when compared with conventional petroleum lubricants, indicated that the poly-glycols possess qualities which make them of particular value in applications where temperatures, moisture and oxidation are factors. Stressing the ability of these lubricants to maintain almost constant viscosity over wide temperature differentials, tho conceding that most synthetic lubricants are more expensive than petroleum products, Dr. Langer concluded, at present, the application of synthetic derivatives should be considered in cases where special properties not found in petroleum lubricants are required. (Submitted by C. A. Pethybridge, Tech. Chrmn.)

Indianapolis (See ASLE Directory for new officers. Submitted by R. C. Fatout, Sec'y-Treas.)

Los Angeles October '53 meeting — A. C. West, California Research Corp., presented a paper entitled Friction and Boundary Lubrication.

December '53 meeting — W. E. Campbell (ASLE President), Brush Labs. Co., Div. of Clevite Corp., spoke on the subject Current Status of Fretting Corrosion.

January meeting — Panel discussion on Centralized Lubrication, with G. E. Jepson, Bowser, Inc., as Moderator, and M. R. Blurton, Alemite Co. of So. Calif., T. R. Costello, Alden Eqpt. Co., A. Walker, Lincoln Engineering Co., and W. Paterson, Trabon Engineering Corp., as Panelists.

February 11-13 — Symposium on Oil Filtration in Modern Industry, sponsored by the Department of Engineering, University of California, in cooperation with the ASLE Los Angeles Section. (Submitted by R. S. McCord, Sec'y-Treas.)

Milwaukee January meeting — W. Oberlin, Alemite Corp., presented a paper entitled Oil Mist Lubrication. (Submitted by R. W. Schroeder, Sec'y.)

Northern California February meeting — H. E. Mahncke, Westinghouse Electric Corp., spoke on the subject Some Consumers Research Problems in Lubrication, in which some of the chemical problems involving lubricants and their behavior which have been worked on by the Westinghouse Research Laboratories were presented. (Submitted by R. H. Decker, Sec'y-Treas.)

Pittsburgh January meeting — Symposium on Steel Mill Slipper Bearings, with W. Ritter, Ritter Engineering Co., as Moderator, and F. J. Gleve, United Engineering & Foundry Corp., J. Simon & J. F. Boal, U. S. Steel Corp., E. J. Hochdanner, Allegheny Ludlum Steel Corp., and S. C. Griffith, Jones & Laughlin Steel Corp., as Panelists, with J. Duchene, American Brake Shoe Co., in charge of illustrative slides. (Submitted by H. K. Siefers, Publicity Chrmn.)

Saginaw Valley January meeting — Annual Ladies' Night, and installation of officers (See ASLE Directory), with A. Liberacki presenting a "magic" show, and color vacation films of the new Treasurer. (Submitted by J. R. Campbell, Sec'y.)

Twin Cities February meeting —

(Continued on page 113)

EVALUATION OF LUBRICANTS FOR THE COLD ROLLING OF BRASS*

by J. W. Johnson
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2700 Passyunk Ave.
Philadelphia, Pennsylvania

ABSTRACT: The coefficient of friction has been used to evaluate brass rolling lubricants under commercial mill conditions. Values ranged from 0.058 for lard oil, used as reference, to 0.081 for a 60 SUS at 100 F., mineral oil. Significant differences were found in different petroleum oils of like viscosity. Of the additives studied, oiliness compounds reduced friction at concentrations as low as 2 to 4% while E.P. compounds had no effect.

A survey of the brass industry in New England in the fall of 1949 revealed that there was need for more basic information on the performance of brass rolling lubricants. An experimental study was undertaken on the evaluation of these lubricants based on an actual brass rolling operation. This paper is a discussion of that investigation and some of the initial results.

In considering the various requirements of a lubricant the reduction in friction was obviously the most important. The lower the friction, the lower the pressure necessary to obtain a given reduction: or for a given mill pressure the greater the reduction obtained. This factor required that the method of evaluation simulate actual commercial rolling conditions as closely as possible. The method of evaluating lubricants was essentially by a measurement of the coefficient of friction on a rolling mill with all variables excepting pressure and reduction in thickness held constant.

Equipment. The mill used was a two-high cold mill with forged steel 12-inch diameter rolls driven by a 75 hp motor. The study of lubricants was limited to the rolling of cartridge brass of 8-inch width in rolls of approximately 1000 ft. Normal and excessive reductions were employed at the customary plant speed of approximately 600 ft./min. The temperature of the steel rolls was kept constant at about 135 F with the use of hot water. The brass strip was oiled by the drip method and wiped to a thin constant film by a pair of wipers just before entrance to the rolls. A constant horsepower motor on the winding roll maintained a constant tension on the exit brass. After rolling the reduction was measured by gauging the strip over a large section of the center of the roll. Gauge was measured to the nearest quarter of a thousandth.

The pressure developed in the rolling experiment was measured by a pair of Baldwin SR-4 Type CS strain gauge load cells, placed one under each "screw-down". These load cells were specially designed for this installation and each one was capable of measuring loads up to 300,000 lbs. with an accuracy of 1%. The output from these cells was recorded on a chart by a Foxboro Dynalog Recorder with chart speeds capable of showing variations of pressure during single revolutions of the mill at full speed operation.

Experimental Method. If all the brass had been rolled to the same reduction a tabulation of mill loads from the load cells would have been a measure of the lubricant efficiency. Or if all the final loads had been the same, a tabulation of reductions would also have been a measure of lubricant efficiency. However, neither of these methods was practically or even theoretically possible.

The method used was to set the idling pressure of the rolls at a given value for each reduction, pass the strip through and obtain total load on the mill and the resultant reduction. In general this amounted to two reductions from .040 to .028 and then from .028 to .022 without annealing. It became necessary then to calculate coefficients of friction from these data to obtain a measure of performance of the different lubricants.

In obtaining a simple and reliable method of comparing the friction-reducing properties of lubricants the expression derived by Stone and Greenberger[1] was used (Equation 1).

$$P = S_o \left[e^{\frac{fb}{T}} - 1 \Big/ \frac{fb}{T} \right] \qquad \text{(Equation 1)}$$

$P = W/b\ell$ = Pressure in contact area lbs/sq. in.
W = Total load on mill = total load cell measurement lbs.
b = arc length of contact
ℓ = width of strip
S_o = constrained yield strength of material = 1.155 x normal yield strength lbs./sq. in.
f = coefficient of friction
T = average strip thickness

The arc length can be calculated from considerations of geometry knowing the roll diameter and the reduction but, at the loads encountered, the steel rolls tend to flatten and the arc length is further increased by this phenomenon. The arc lengths were calculated by the equation of Trinks and Hitchcock[2] (Equation 2).

$$b = \sqrt{R(T_1-T_2) + 16\,WR\,(1-\sigma^2)/\pi\ell\,E} \qquad \text{(Equation 2)}$$

R = roll radius
T_1-T_2 = reduction
σ = Poissons Ratio 0.3 for steel rolls
E = modulus of elasticity of rolls 29.5×10^6

The first part of the expression represents the

*Sponsored by the ASLE Technical Committee on Fluids for Metal Working, and presented at the ASLE 8th Annual Meeting, Boston, April 14, 1953.

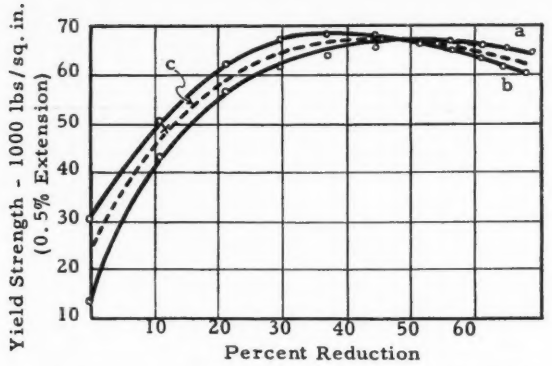

Fig. 1 Relation between yield strength and reduction for F-37 Cartridge Brass. (a) .070 grain size, (b) .015 grain size, (c) .040-.045 grain size F-37 used at Bridgeport Brass Co., interpolated from a and b. (x) averaged value estimated for 30% reduction. Data for a and b from Wilkins and Bunn "Copper and Copper Base Alloys."

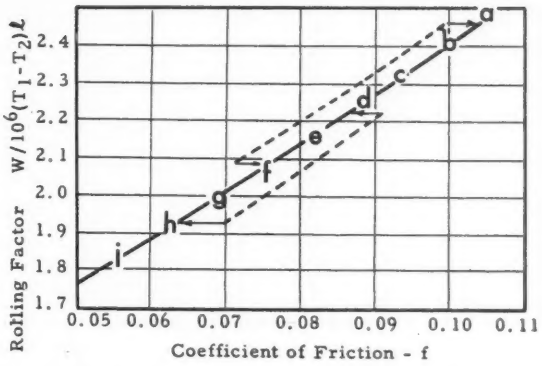

Fig. 2 Relation between coefficient of friction and rolling factor for F-37 Cartridge Brass. Conditions: first pass, .040 gauge, .045 grain size. Average yield strength: 47,000 lbs./sq.in. Roll diameter: 12.55-in. Load/in. of width (thousands of pounds): a, 30; b, 29; c, 28; d, 27; e, 26; f, 25; g, 24; h, 23; j, 22.

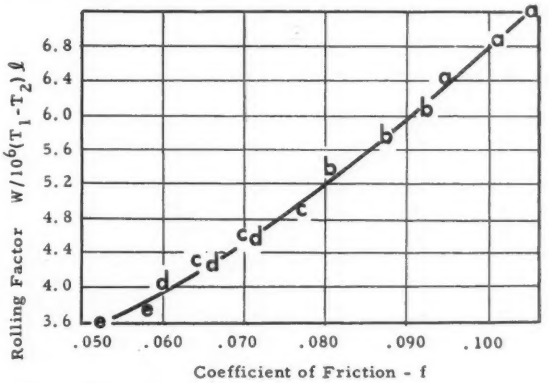

Fig. 3 Relation between coefficient of friction and rolling factor for F-37 Cartridge Brass. Conditions: second pass, .028 gauge, .045 grain size. Average yield strength, 66,500 lbs./sq.in. Roll diameter: 12.55-in. Load range: Load/in. of width (thousands of pounds) 32-36. Reductions: a, .005; b, .006; c, .007; d, .008; e, .009.

arc length due to the geometry of the reduction and the second part represents the arc length due to roll flattening.

It can be seen from the Stone and Greenberger equation, which has a theoretical basis, that the coefficient of friction could be calculated from the experimental data if the S_o were known.

Unfortunately the yield strength of brass varies with reduction. This relationship for cartridge brass is shown in Fig. 1[3]. It can be seen that the yield strength varies greatly up to a reduction of 35% and then remains at a fairly constant value out to a 60% reduction.

At this point the assumption was made that the lubricant would have the same coefficient of friction throughout the reduction range. A figure of 47,000 lbs. appeared to be a good average yield strength for a 30%—1st pass reduction and 66,500 lbs. for the second pass out to a reduction of 50%.

To eliminate the estimation of S_o from all future calculations, a new relation was derived. Using a figure of 47,000 lbs. for a 30% reduction the coefficients of friction for a series of mill loads were calculated from the Stone equation. Then a rolling factor Load/10^6 x Reduction x Width was plotted against the calculated coefficient of friction. This relation is shown in Fig. 2 for a wide range of mill loads covering the operating range of the Bridgeport Mill. If a lower reduction (0.0105") and a higher reduction (0.0135") were treated similarly at the same yield strength, dotted curves for these two reductions would lie on either side of the solid curve. It is quite apparent from Fig. 1 that the lower reduction would have a lower average yield strength than the 30% figure. There are several ways to estimate what the correct lower yield strength might be, based on the fact that 47,000 is assumed to be the correct figure for a 30% reduction. A ratio of final yield strengths (62.5)/(64) times the 47,000 would be one method. Using this estimated value for the lower reduction moves the dotted curve over to within 1% of the solid curve. The same holds for the higher reduction. Since the accuracy of the load measurements and the gauge reduction are of this order of magnitude these curves can be considered to coincide. The solid curve then represents a very quick method of calculating the correct coefficient of friction without any necessity to correct for small changes in the yield strength for small differences in reduction.

For the second pass from 30% reduction down to 50% reduction, a value of 66,500 lbs. for the average yield strength is accurate enough. The rolling factors for the second pass for a wide variety of reduction over the mill range of loads are also plotted against coefficient of friction and fall within 1% of a smooth curve (Fig. 3). Use of these two plots enables ready calculation of the coefficient of friction of the two passes, the first approximately from 0 — 30%, and the second from 30% to 50%. These two figures are averaged for the experimental coefficient of friction of the lubricant tested. These two figures are not independent of each other for the exit gauge of the first pass is the entrance gauge for the second pass. Any errors in gauging the thickness after the first pass are automatically compensated by averaging the coefficients of friction for the first and second pass. Thus the variation of the coefficient of friction due to error in the gauging is only a function of the initial (0.040) and final gauges (0.020). An error of ¼ of a thousandth would produce an error of ± 1% in the coefficient of friction.

This rolling factor, which is essentially a ratio of load to reduction for any given strip width is an excellent way to check rolling lubrication on any

Reduction Range %	Resistance to Compression P = W/b	From Yield Strength Graph #1 Average of Initial & Final Y.S.	#2 Y.S. of Average Reduction	Average of #1 & #2	Average Exp. Y.S.
0-10.8	53	35	37	36	37
0-18.5	63.5	39	44	41.5	41
10.8-18.6	72	51	52	51.5	50
0-29.3	80.8	43	51.5	47	47
18.4-28.5	88.5	59.5	60.5	60	58
18.5-40.0	111	62	63	62.5	62
29-39.3	112	65	66	65.5	67
29-46.3	123	65	66.5	66	66
39.7-51.8	130	67	67	67	68.5

All figures 1000 lbs./sq.in.

% Oiliness Additive	% Extreme Pressure Additive	Viscosity of Oil @ 100° F.,S.S.U.	Coefficient of Friction
2	0	100	0.071
2	0.5		0.071
2	1.0		0.070
2	2.0		0.070
0	0	100	0.074
2	0		0.071
4	0		0.069
2	2	100	0.070
2	2	200	0.070
2	2	300	0.069

100% Lard Oil = 0.058

Table I (top) F-37 Cartridge Brass — Bridgeport Brass Co. Grain size .040-.045, gauge = .040 nominal.

Table II (bottom) Typical compounded metal oils.

mill equipped with pressure reading devices. For any production rolling this ratio should be a constant for any given lubricant.

Experimental Check on Method. In Table I are summarized the reduction experiments on seven rolls of cartridge brass, all reduced 50% by a variety of reductions. These experiments were run to (1) check the assumptions previously made, (2) check the reproducibility and accuracy of the method and (3) to obtain a method for predicting the correct average yield strength for any reduction. The seven coils were all run, using the same oil, in the sequence shown in the table. This oil had a coefficient of friction previously determined as 0.080. The third column lists the resistance to compression and is calculated from the total mill load and the reduction. The values in the table are an average from at least two and up to four different coils. These individual values (not shown) indicated good agreement between experiments. They also indicated that the compressive resistance in any range is not affected by past history of the particular coil. The last column lists the experimental yield strengths calculated by using the Stone and Greenberger equation. The center of the table lists two methods of estimating average yield strength from the graph in figure I. An average of the two methods checks quite well with the experimental value. This is particularly true where the reduction range is wide (0-18 and 0-30) and reflects that the curve is not a straight line but is concave down. An average of the two methods tends to correct for this. This method of estimating the average yield strength would enable one to calculate mill pressures for any alloy for which yield strength curves are available.

Evaluation of Rolling Lubricants. The purpose of this study was to develop superior rolling oils through the use of the best oils and the best friction reducing additives. A large number of oils both compounded and uncompounded were evaluated by this method. A large spread in the value of the coefficient of friction was obtained which varied from

% Oiliness	% E.P.	Oil	Coefficient of Friction for 100 Vis. Oil	200 Vis. Oil
2	2	Type X	0.070	0.068
2	2	Type Y	0.065	0.065
2	2	Type Z	0.061	0.061

100% Lard Oil = (0.058)

Vis./100°F.,S.S.U.	Coefficient of Friction for Oil Type X	Type Y	Type Z
60		0.081	
100	0.073	0.072	0.066
150			0.067
200	0.071	0.070	
300	0.075	0.062	0.060

100% Lard Oil = 0.058

% Oiliness	% E.P.	Coefficient of Friction for 200 Vis. Type X	60 Vis. Type Y	200 Vis. Type Z
0	0	0.071	0.081	0.067
2	2	0.071	0.069	0.066
4	2	0.070	0.068	0.056

100% Lard Oil = 0.058

	Roll Diameter	Surface	Coefficient of Friction
#1	12.55	Normal production type	0.064
#2	12.28	" " "	0.058
#3	12.28	" " "	0.059
#4	12.43	Slightly rougher for experimental purposes only	0.073
#5	12.43	Same surface no change	0.067
#6	12.43	Same surface roughened	0.079

Table III (top) Compounded metal oils; effect of type of mineral oil.

Table IV (second from top) Mineral oils.

Table V (second from bottom) Compounded oils.

Table VI (bottom) Effect of steel roll surface on friction; roll oil = **100%** Lard Oil.

approximately 0.060 for 100% Lard Oil to 0.080 for a mineral oil without compounding. Throughout this work 100% Lard Oil was used as a control to establish a lower level of friction reduction. This figure could also be used to compare oils run at different times and on different roll surfaces.

Table II indicates that for a typical compounded oil variations in the amount of extreme pressure agent or variations in viscosity do not produce any marked effect on the coefficient of friction. The friction varies definitely with change of concentration of the oiliness additive. This was not unexpected.

Table III indicates the effect of the type of the mineral oil base made up with normal compounding. Here again there is no indication of variation of friction with viscosity. However, there is a remarkable difference in friction based on the choice of mineral oil base. This finding was somewhat unexpected and led to a study of the mineral oils without compounding (Table IV). Oil types Y and Z appear to be much superior to type X. Also noteworthy is the fact that with these two uncompounded oils viscosity has definite effect on the friction. The 300 viscosity oils show excellent friction reduction, but in general this viscosity level is believed to be too high for clean annealing. Table V shows the comparison of oil Type Z with Oil Type X at the same viscosity as the oiliness content is increased. At the highest level the 200 vis. Oil Z has friction properties equivalent to pure lard oil. This was confirmed in later experiments. By using Oil Type Y which is available at the 60 viscosity level it is possible to compound a rolling oil equivalent to those made from Oil Type X at the 200 second level. The desire for the very light viscosity oils is due to the ease with which they volatilize in the annealing furnace leaving little or no stain.

The effect of the steel roll finish on frictions is shown in Table VI. All values for coefficient of friction are for 100% Lard Oil. The first three determinations were on normal shop surfaces in between normal rolling schedules. They indicate how closely the grinders can approximate the surface from roll to roll. Experiment #4 was a deliberately rougher surface which immediately reflected in a higher friction value. Experiment #5 is a check on # 4. Surface #6 was on the same roll as #4 and #5 but at a later date. Inability to 'stick" the first coil led the operator of the mill to conclude that the rolls were too slippery. Before he could be stopped he had roughened the rolls with abrasive paper. The increased friction shown in experiment #6 resulted. The data in Table VI indicate that surface can play as important a part as the lubricant.

The above data are a small part of a rather extensive study of additives, oil bases and synthetics covered in the program at Bridgeport Brass Company but indicates the progress that can be made, with fundamental approach to a lubricating problem.

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Book Reviews

Elements of Internal Combustion Engines, by Prof. A. R. Rogowski, Massachusetts Institute of Technology; McGraw-Hill Book Co., Inc., Publishers, 1953, 234 pages.

This book, relatively brief for its field, was written primarily as a text for a one semester course on internal combustion engines. Elimination of details and reduction of subject matter, which non-specialists would consider as superfluous anyway, have accomplished this purpose.

The material is concise and straightforward, commencing with a review of fundamentals and proceeding through real cycles, friction, combustion, combustion phenomena, carburetion, ignition, fuel injection and performance. Emphasis placed on air breathing capacity is noteworthy since it not only illustrates the manner by which most of the recent gains in specific output have been accomplished, but also amplified the axiom that "all things otherwise equal, the output of an engine is directly a function of air handling capacity."

Although intended primarily for the classroom, it would appear that this book would serve equally well as a general review or non-technical reference for practicing engineers and others who are concerned with internal combustion engines and for whom more complete details of design and performance are not important.

While the omission of the gas turbine has no doubt been done in the interest of brevity, the reviewer feels that such omission is of concern, since it seems apparent that the gas turbine not only qualifies under the subject, but also is progressively increasing in importance.

E. Starkman
Univ. of Calif.

Personals

C. E. Schmitz (former ASLE President), Vice-President & General Sales Manager of Crane Packing Co., Chicago, Ill., has been appointed Director of the National Conference on Industrial Hydraulics for 1954.

The DeLaval Separator Co., Poughkeepsie, N. Y., announce expansion of their Industrial Division with new quarters at 2420 Grant Bldg., Pittsburgh, Pa.

Acting on the need for diversified discussion on overall activities in the chemical and processing fields, the **Cleveland Engineering Society** has announced the formation of a **Process Industries Division.** Designed to bring together men in the northeastern Ohio chemical and processing fields, the new group will cover general technical subjects not within the scope of existing groups which concern their programs with the specific problems of industry.

J. L. Finklemann, Vice-President in Charge of Manufacturing & Research, announces the expansion of the plant facilities of **The Warren Refining & Chemical Co.**, Cleveland, Ohio.

Officers & Directors of Standards Engineers Society reelected for 1954 include: **W. L. Healy,** General Electric Co., President; **M. S. Gokhale** & **F. M. Oberlander,** RCA Victor Div., Vice-President and Secretary, respectively; **H. J. Nugent,** Manufacturers' Representative, Treasurer; **H. G. Arlt,** Bell Telephone Labs., Inc., **W. G. Baird,** IBM Corp., and **V. S. Gittens,** Philco Corp., Directors.

Obituary: **D. M. Blakey,** Topp Oil & Chemical Co., Milwaukee, Wisc., January 27.

Lubrication in the News

Saybolt Viscosimeter. A new constant temperature Saybolt Viscosimeter, employing electronic circuit with mercury thermostat, has been announced that uses double wall insulated construction, with stainless steel exterior and Bakelite cover. Stirring is done by an external induction motor with turbine type impellor; thermo-regulator is mercury type, easily adjusted through full temperature range. Made in both 2 and 4-tube models, and temperatures up to 450 F., the units are available for 115 and 230 volts A.C. current. Write for Bulletin 4510, Labline Inc. (LE10/2), 217-221 N. Desplaines St., Chicago 6, Ill.

(Continued on page 111)

FORUM ON HYDRAULIC TRAINING*

R. Q. Sharpe, Forum Chairman
Socony-Vacuum Oil Co., Inc.
26 Broadway
New York 4, New York

ABSTRACT: An Hydraulics Forum was held at the ASLE 1953 National Meeting for the purpose of developing ideas and interest in better training of designing engineers, manufacturers' service representatives, and plant maintenance and operating personnel in the design, operation, adjustment, and mechanical details of hydraulic equipment and circuits as applied to industrial machinery. The same ideas and principles will apply to the application of hydraulics to other industries. The meeting was conducted by R. Q. Sharpe, Staff Engineer of the Socony-Vacuum Oil Co., Inc., with a four-man panel representing an industrial training school, a manufacturer, a large user, and a supplier of component parts. Papers of the panel members are presented herewith in condensed form together with abstracts of the questions and answer period.

F. L. MACKIN, General Motors Institute: Today we see the increasing use of hydraulic controls not only on industrial equipment but in other important fields, such as modern automobiles, airplanes, and earth-moving and farm equipment. Hydraulic mechanisms in these applications easily provide great power for the control of such diverse things as fluid couplings, brakes, power steering, airplane control-elements, and plow blades. Illustrative of the extensive application, a recent survey showed that 95% of the industrial production equipment in a particular plant used hydraulic controls of some type. With such wide application of hydraulics, it is necessary that the people who must design, construct, adjust and maintain this equipment be trained in fluid mechanics, hydraulic circuits, and the mechanics of adjusting and maintaining the various elements of hydraulic equipment. Only through such training can we expect equipment that is soundly designed, properly constructed and applied, suitably adjusted and well maintained.

Such training is the combined responsibility of our high schools, colleges and industry or vocational technical schools. The schools and colleges will have the basic responsibility for teaching the designer the elements of good mechanics and proper design which will simplify manufacturing methods and assembly. The construction and application phases of the training are primarily the responsibility of the manufacturer and will be accomplished by on-the-job training with probably some related technical training.

Once the machine is built, the set-up and adjustment of the machine, as well as its subsequent maintenance, requires a general understanding of both the principles of fluid mechanics and the functioning of various types of electrical and hydraulic controls. A mechanical aptitude is also necessary to coordinate the various items. Most hydraulic controls today are a combination of electrical and hydraulic units. It is necessary, therefore, that the man who adjusts and maintains the machine have a general understanding of electrical circuits, as well as hydraulic circuits, and the functioning of various types of actuating devices used in each. Such information usually will result from on-the-job training on the part either of the manufacturer or the user. In most instances, the men who will handle the adjusting and maintenance of this equipment will be provided by industry.

Another phase of hydraulic training which must be considered is the application of fluid couplings and torque converters which deals primarily with what might be termed hydrokinetic rather than hydrostatic energy. The fact that one fluid-coupling manufacturer reports 5,000,000 hp of fluid couplings applied to industrial hydraulic-equipment indicates its magnitude in industrial and automotive equipment. This again emphasizes the desirability of wider training in fluid mechanics.

P. H. EMRICH, Vickers Inc.: During the past 5 years more than 750 men from over 400 companies have attended the Vickers Practical Hydraulic Maintenance Training Program. This figure does not include those trained in the field and in special programs at the plant.

This school was organized initially with two primary objectives: (1) Create better product understanding (Increased knowledge of hydraulic system elements), (2) Provide proper "know how" for operational trouble-shooting, scheduling overhaul and interim checks.

A recent third objective has been to teach effective use of a Product Service Department by maintenance departments of equipment users. This includes planned replacement-parts programs, product improvement to increase unit service life, and a more effective use of field-service representatives and factory repair-and-exchange programs.

Admission to the course is by invitation only and, while no formal educational requirements have been established, the student is expected to be familiar with general problems connected with hydraulically operated machinery. This 11-day course is conducted at the builder's plant by instructors who are specialists in their respective field. The course covers such basic subjects as elementary hydraulics, various types of valves, controls, pumps and fluid motors. Representative hydraulic circuits are analyzed and explained. Lectures are supplemented by practical laboratory work in the assem-

*Sponsored by the ASLE Technical Committee on Hydraulics & Hydraulic Machinery, and presented at the ASLE 8th Annual Meeting, Boston, April 14, 1953.

bly and disassembly of equipment and the setting up of circuits. Slides, films and other helpful props are also used. Students are encouraged to participate actively in the lecture and laboratory sessions and to carry on discussions during their off time. Examinations are given frequently on the various subjects carried in the course. At the conclusion of the school, the student receives a reference manual.

The importance of hydraulic maintenance training cannot be overemphasized. It has been established that hydraulic maintenance costs can be reduced on the average by 20% through proper training of maintenance personnel. Machine down time also may be reduced and in one outstanding example, down time of a machine was reduced from 300 to 50 hours per month.

Schools and industry can and should cooperate fully to provide more and better training.

E. LERCZAK, Oldsmobile Div., GMC: In 1948 Oldsmobile tooled the ultramodern Rocket Engine Plant with the most modern machine tools, of which a high percentage contain hydraulically operated components.

Their management realized that few of their maintenance men had sufficient experience and training to service these modern hydraulic tools properly. Furthermore, many of the maintenance men normally used had been moved on to other job classifications. Maintenance men especially trained in hydraulics could neither be hired nor was it practical to send Oldsmobile employees away from the plant for special training. Therefore, in January, 1949, a program of "On-the-Job" training of maintenance men in hydraulics was started.

An area within the plant was set aside as a laboratory and class room, and was equipped with replacement hydraulic units and other teaching aids. A qualified instructor was secured and arrangements made for conducting classes during the men's normal working time without charge to them. In fact, they received their normal wages while taking the course. All books, supplies and other expenses were provided by the company. Careful scheduling of men from the various repair stations reduced to a minimum the necessity of shuttling men from one repair station to another for emergency work while classes were in session.

Weekly 4-hour classes are currently held for 24 weeks, providing a total of 96 hours of instruction. The first hour of each session is for discussion of the particular subject. During the remaining 3 hours the men work in teams to disassemble, study and reassemble hydraulic components and, ultimately, complete hydraulic circuits. The course covers principles of hydraulics, basic components and, finally, complete standard circuits. Since the men are working in the plant with many of the same components used in the class, it is easy for them to translate their class room work into their daily maintenance and adjustment of hydraulic equipment. For example, the multiple circuits of a large station-type transfer machine thus becomes simplified in the minds of the men, with much more effective maintenance and adjustment. During the course each man is rated periodically, and at a banquet provided by the company a certificate of accomplishment is presented to each man completing the course.

Each student is nominated by his supervisor and taken from the regular groups of machine repairmen, pipe fitters, electricians, or apprentices in these trades. This training is supplemental to the men's respective trade training and provides a common ground of knowledge between the trades in handling complaints on the production floor. A maintenance man is still expected to concern himself only with items of his trade, but the common knowledge of hydraulics is especially helpful where the trouble concerns more than one trade classification. In Oldsmobile, the hydraulic school has eliminated the necessity of establishing a separate job classification of "Hydraulics Serviceman," although such a classification has been found desirable in some companies.

Despite the fact that 143 men have received certificates and 38 more are receiving training in the hydraulic school, interest in the course is increasing rather than declining, and it is planned to expand the course to include engineers and supervisory personnel. As a result of the school, more effective repairs and adjustments are being made which has resulted in equipment operating for longer periods between repairs and substantially reducing production machinery down time. While it is true that improved design as well as a comprehensive preventive maintenance program have contributed to this beneficial result, it is felt that the hydraulic school has been an important factor in this increased efficiency.

H. BLAIR, E. F. Houghton Co.: As a manufacturer and supplier of mechanical packings for hydraulic equipment, the technical service which is given with our products provides daily contact with personnel dealing with mechanical and pneumatic hydraulic elements. Consequently, the man selling hydraulic components often acts as a maintenance counselor in the proper technique for installing and using those elements. Since time limits the extent to which this may be practical, it seems that industry can help themselves materially by training their men to a better understanding of hydraulics.

For example, an unexplained premature failure of leather "U" ring packings in one case, which previously had been providing long service life, was found to be caused by failure to drill pressure balancing holes in a new pedestal ring which had just been installed. Had the maintenance men understood the hydraulic principles involved in this packing, they would have understood the desirability of balancing the pressure across this ring to prevent displacement of the "U" ring packing, and the failures would not have occurred. As another example, a large plant in the Detroit area found it necessary to forbid the night-shift maintenance crew from making major disassembly of hydraulic machines. It was found that very often the night crew tore a machine down, without being able to diagnose the trouble. This often put a machine out of production for more than one shift. The more skilled day crew often could remedy operating faults by some simple adjustment without the necessity of a major disassembly. Since properly trained men could not be secured for the night shift, it was cheaper to have the machine out of service for one shift until the day crew came on rather than have it serviced by untrained night men.

Many manufacturers and users of hydraulic equipment recognize the critical need for personnel trained in industrial hydraulic equipment, often hiring engineering graduates and training them in Hydraulics. However, one Chief Engineer observed that the mortality rate of those completing the course was so high in losses to competition and industry that he despaired of holding enough men for his own needs. Many training programs are lagging because of lack of time, instructors and facilities. Much can undoubtedly be accomplished by more intensive training in technical shcools and colleges. Expansion of this field of training requires educating schools and industry to the need for a greatly expanded educational program in hydraulic machines. This phase of hydraulics must be clearly separated from civil hydraulics, dealing with water power, flood control, etc. It is believed that the ASLE can be instrumental in promoting increased activity among our schools and colleges in the training of students in industrial hydraulic equipment.

QUESTIONS & ANSWERS

Q. What does the panel recommend to help the smaller user of hydraulic equipment train his personnel? (Mr. Knapp, Denison Engineering)

A. Make use of courses offered by manufacturers of hydraulic equipment, as well as information provided by vendors. (Blair)

A. Develop community interest in hydraulic training in high schools and technical high schools. (Mackin)

A. Shorten training courses to satisfy users with limited amount of equipment. (Emrich)

Q. Mr. Lerczak spoke of testing their trainees periodically. I would like to know if that is a written test or a verbal test. (R. D. Bussard, Ladish Co.)

A. The men are tested 3 times during the course with the first two tests very short while the last is a complete written test covering the entire course. (Lerczak)

Q. I think the people that apply hydraulic systems should have diagrams which are just as good as those on electrical equipment. What is the opinion of others? (C. L. Pope, Eastman Kodak Co.)

A. One of the basic requirements of the JIC Hydraulic Standards is that, when requested by the purchaser, the hydraulic diagram should be furnished with the machine. (Mackin)

A. In most of the courses that are taught a great deal of time is spent on circuit diagrams because they are the foundation for understanding the system and diagnosing malfunctions. (Blair)

A. Three kinds of diagrams are being used today. First, the pictorial diagrams; second, the cross-section diagrams; third, symbolic diagram using standardized hydraulic symbols. (Mackin)

A. Each of our three main divisions at the plant has a file copy of all the circuits of all the various hydraulic machines in a book together with a write-up step by step of the sequence of operation. We are trying to get a circuit diagram mounted in the electrical control cabinet alongside the electrical diagram for each hydraulic system. This is being handled by our own Engineering Department. (A. Steele, Scovill Mfg. Co.)

Q. Overloading of hydraulic systems is quite common in our plant and I would like to know if there is anything in the JIC Standards which prevents overloading circuits by boosting pressures excessively high. (A. W. Salzman, Racine Hyd. & Mach. Co.)

A. In one of our JIC Standards we stated that a relief valve should be so designed that it could not be adjusted beyond its functional limits, and I know that several companies have already made that change in their valves. However, men that are properly trained will realize that excessive pressures are undesirable and will avoid them. (Mackin)

A. One of the reasons for this Hydraulic Forum Program is that no set of standards can take care of lack of understanding on the part of a user. With the JIC Standards you may obtain prints and other information that you need to maintain equipment properly after you have the trained personnel. (D. Morrell, Ford Motor Co.)

Q. How do you overcome the problem of making a specialist out of a man who then thinks he is so important he doesn't want to do anything else? (C. L. Pope, Eastman Kodak Co.)

A. The machine repairmen to whom we have given training are carrying on their normal duties. This is merely a supplement to their training and we do not consider we are making specialists out of them. (Lerczak)

Q. I have heard quite a bit here about valves, springs and seals, and wonder where I can get corresponding information on hydraulic fluids and their proper maintenance. (Mr. K. Eisens)

A. Some of our best students have been people from the oil companies. We like to encourage their attendance because we look to them to recommend proper fluids. They also have a great number of trained field personnel to go out and teach proper oil maintenance. I think your best source of information on this subject is the oil companies and other suppliers. (Emrich)

A. To Mr. Emrich's comment, I should like to add that the Education Committee of ASLE has publications on various phases of lubrication and lubrication practices. These too will be helpful in educating the user in the proper use of fluids. (Sharpe)

Current Literature

Lubrication Trends, Part II, by W. A. Zisman; Canadian Chemical Processing, Vol. 37, No. 12, Nov. 1953, pp. 68, 70, 72.

Friction and wear research, polar-type liquids, adsorption effects, soap properties, sulfur and chlorine compounds, hydrocarbon properties, ester lubricants, polyalkylene oxides and detergent additives are discussed.

The Electron Microscope in the Petroleum Industry, Anon.; Lubrication, Vol. 39, No. 12, Dec. 1953, pp. 141-152.

Use of the electron microscope, because of its high resolving power, makes the shape and structure of particles, too small to be seen with the light microscope, visible. Length, width, thickness and state of aggregation of particles can be determined. It is not yet possible to define the limit of usefulness of the electron microscope. Its use in the petroleum industry to study soap fibers in lubricating greases, additives in lubricating oils, catalyst particles and wear surfaces in bearings or other friction problems is discussed.

Is Silica the Best Heavy-Oil Additive?, Anon.; Oil & Engine Gas Turbine, Vol. 21, No. 245, Nov. 1953, p. 277.

Three years ago the search began for a cheap additive to inhibit ash deposition or corrosion, or both, in residual-oil-burning gas turbines. Pametrada, the Shell Group, and Sulzer Bros. in Switzerland have found ethyl silicate gave very encouraging results. Sulzer Bros. tested inorganic silica compounds such as kaolin and kieselguhr and found them very effective. More research on the subject waits to be done. The next problem will probably be arrangements for feeding and metering such substances as kaolin and kieselguhr.

Trend in Lubrication, by W. A. Zisman; Canadian Chemical Processing, Vol. 37, No. 11, Oct. 1953, pp. 88, 90, 92.

Antioxidants, rust inhibitors, detergency, viscosity index improvers, greases and general trends in lubricants are discussed. Synthetic "tailor-made" oils will be used increasingly. Synthetic lubricants will be used mainly in equipment requiring long periods of operation without maintenance, in complex or delicate equipment whose relubrication is best handled during partial or complete disassembly, and in equipment required to operate at an extreme temperature or over a wide range of temperatures.

Graphitizing & Non-Graphitizing Carbon Compound — Formation, Structure & Properties, by R. E. Franklin; Brennstoff-Chemie, Vol. 34, No. 23/24, Dec. 16, 1953, pp. 359-361.

At 2000-3000 C., some carbon containing compounds are converted into graphite, while others are not. The

(Continued on page 113)

OILY INDUSTRIAL WASTES*

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ABSTRACT: The following paper discusses industrial wastes and some problems related to their control. Voluntary activities in prevention of such wastes are highlighted as being more economical and practical than extensive treatments after occurrence. Highly technical discussions have been avoided to provide a more acceptable solution of a perplexing problem by commonsense methods.

The term "Industrial Wastes" may be applied to those materials which are no longer of economical value at their point of origin. It does not follow that they are necessarily true wastes and have no value. Thus, sawdust and wood trimmings, of little use to a sawmill where they originate, may be treated and molded under proper conditions into highgrade wall board or structural material of high quality and utility. The same is true of many other industrial wastes including those of oil fuels and lubricants. Location and quantities available determine whether or not such products can be gainfully utilized. When unwanted oils, fats and greases are dumped upon the ground or into streams or sewers, their value can only be measured by their nuisance-causing characteristics. They have become true wastes incapable of any means of economical recovery. As such, they must be segregated and destroyed by burning to prevent actual health, fire or property hazards.

Unfortunately, the need for preventive or curative measures to combat contamination is not always apparent until conditions become intolerable. Too often the need is brought to light by legal or punitive actions on the part of individuals or authorities. Once such actions are started, the offender usually has a difficult time regaining the prestige formerly enjoyed and can regain it only at great expense. Adverse publicity usually accompanying such actions may seriously affect efforts of the offending firm or individual to remain in business. It is rather difficult for the ordinary individual to remain friendly to a business which carelessly endangers his health, recreational facilities and perhaps even the lives of himself and his family through indiscriminate disposal of obnoxious or harmful wastes.

Voluntary efforts on the part of a potential offender in combating or eliminating contamination, if initiated prior to legal actions, are rewarded by intangible returns in the way of improved public relations and by tangible returns in the way of values of recovered products or by-products.

It may be well to mention here that the recovery of products from wastes is seldom, if ever, profitable. Very few recovered products, even if salable or usable, ever give financial returns commensurate with costs of treatment or recovery and the recovered products are seldom in high demand.

Excessive contamination of streams and surroundings is seldom deliberate but is usually due to carelessness or lack of foresight in the operation of what would otherwise be considered a well-conducted business. In the past, many types of wastes have been disposed of by most convenient means, usually by streams or sewers, with utter disregard of the rights of others and of the consequences of such indiscriminate disposal. As a result, many of our formerly beautiful streams have become "dead rivers" and our lakes unsightly and unfit for recreational purposes.

Petroleum Solvents. Used petroleum solvents, if dumped into sewers or upon the ground or even into streams are, at best, a potential fire or explosion hazard. Volatile fumes may affect workers in sewers. They may also do great physical damage when carelessly or accidentally ignited. Alternatively, many of these materials could be collected and made into usable products by redistillation or other means. Reclamation may be done either in the plant of origin or in plants specializing in such products. Recovered products may be entirely satisfactory in every way for original use. Costs per gallon for recovery in some cases can be a fraction of the original costs of new materials when large quantities are involved and when a segregation program is practiced to prevent mixing of certain types of solvent wastes.

Lubricating Oils. Lubricating and hydraulic oils, if allowed to escape through leaky or faulty equipment, usually find their way into streams or sewers. They coat the surface of the water with a film of oil, thus shutting off oxygen needed by aquatic plants and animals. They also use up much of the oxygen dissolved in the water and thus hasten the early demise of all types of stream and pond life.

Oily materials of these types may be profitably collected by skimming devices and dried or further processed to provide suitable materials for blending, fuel or other uses. Once they are allowed to escape to sewers, they become an especial public problem in localities having sewage disposal facilities. Costs of skimming off oils mixed with sewage are surprisingly high and do not result in recovery of useful products. The recovered products must be burned as they are so badly contaminated with other refuse as to preclude economical processing. The resultant disposal by burning creates another problem, namely atmospheric pollution.

Segregation of Wastes. When costs of recovery

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at the source are weighed against costs after indiscriminate disposal, the balance will be found in favor of the former even without regard to the value of the recovered products.

To cite an example: A manufacturing firm, a number of years ago, decided to initiate a recovery program involving oils. An oil interceptor of an approved design was built and used to recover and hold oils coming out of the plant. Due to the excellent design of the apparatus, very little oil escaped. Attempts were then made to use the recovered oil for blending with cutting oil bases for use in machining. It was discovered that quantities recovered were too small to permit this practice and pay processing license fees required and the cost was higher than the equivalent commercial products. It was estimated that about two times the recovery in volume would be required to make the process economical. The result was that the firm in question is now pumping the recovered oils to the power house where they are mixed with the power house fuel supply and burned under the boilers. The full value of the same volume of fuel oil is thus gained without extra processing.

In the case cited, it is questionable whether amortization of equipment installed will take place very rapidly or even cancel costs during the life of the equipment. One thing is certain, however, a distinct nuisance with indeterminate costs has been avoided. With the growth of the plant in question and with continuance of the recovery program started, a potential profit does not seem too remote. Such programs of recovery have a great deal to recommend them, aside from a monetary point of view, on the basis of public relations.

Soluble Oil Emulsions. Recovery programs connected with treatment of petroleum products are usually not simple particularly when wastes consist wholly or largely of soluble or emulsible oils. Here the problem of recovery or disposal becomes highly complicated due to the small returns and increased effort required.

Waste oil-emulsions, if allowed to enter streams or lakes, immediately spread throughout the body of water from top to bottom. They coat all objects in contact with the water with a film of soap or oil. Soaps formed through reaction with the lime or other mineral content of the water are quite insoluble in the water as a general rule. Mineral oils thus released through decomposition of the emulsion provide the same nuisance value as would an equivalent amount of oil allowed to escape from any other source. If mineral oils are already present on the water, waste emulsions may even assist in emulsifying them thereby increasing the pollution problem.

Mixture with alkaline wastes may stabilize the emulsions and permit them to spread even further.

Unlike mineral oils, no promise can be made that any program capable of any returns commensurate with effort expended is possible in the treatment of this type of waste. However, due to the far-reaching effects of soluble or emulsible oil wastes, when permitted to enter streams or water courses and the results of indiscriminate disposal of them, every effort must be made to control or eliminate them, regardless of cost.

When present in streams or lakes from which public water supplies are obtained, the expense of purifying such water is prohibitive and places a heavy burden upon the community as a whole. Firms causing the pollution may themselves be in the position of requiring more satisfactory water supplies through their own carelessness.

Soluble or emulsible oils may be disposed of only by somewhat complicated chemical and physical processes. In many cases the ingenuity of highly skilled technicians may be required to solve the problem. Emulsions must be "broken" by chemical means to allow separation of constituents. Removal from the treating chemicals may also present a disposal problem. Separated oils may be skimmed off, as in the case of straight mineral oils discussed above. The remaining soaps, and chemicals used in treatment, also require disposal in a manner which will not aggravate the pollution problem.

Perhaps the best treatment of all starts at the point of use. Any means which prolongs the useful life of the emulsified oils through aeration, settling, filtration and addition of proper bacteriacides will markedly alleviate disposal problems or even make a disposal problem unnecessary. Proper pH control of solutions and avoidance of mixing with mineral oils, in themselves, do much toward extending the life of such materials. A program of cleanliness and care at the right time in the shop is also most helpful.

Some ingenious methods of soluble-oil waste disposal are possible in certain cases. Attention has been called to one firm which sprays soluble oil wastes on its coal supply to prevent dusting. Another sells such wastes to firms in the business of spraying roads to allay dust.

Usually, in a plant of any size, availability of other wastes may simplify treatment of soluble oil wastes. For example: If both soluble oil wastes and acid wastes such as pickling wastes occur in the same plant, the acid wastes may be used to break emulsions in rather simple installations. The released oil may then be skimmed off and reclaimed while the acid effluent may be allowed to flow over limestone for neutralization or, if space is at a premium, may be neutralized with lime. If alkaline wastes occur in the plant, they may be employed to neutralize excess acids by conducting them to the point where acid effluent leaves the skimmed oil. If acid wastes are high and insufficient alkaline wastes available for complete neutralization, lime may be used to supplement them. Careful study may avoid high costs and eliminate purchase of expensive equipment and additional chemicals. The latter must also be disposed of in such a manner as to not aggravate the pollution problem. If a separate installation is provided for each type of waste, disposal costs may become enormous and entirely out of proportion in solving the problem in an efficient manner.

Miscellaneous. Many services and types of equipment are offered by firms specializing in waste disposal and treating equipment for disposal of soluble oil wastes. These may range from simple installations to highly complicated and expensive ones. Effectiveness is not necessarily related to complexity. Maintenance and operating costs must be considered as well as original costs of equipment.

It may be well to consult with local and state authorities before providing expensive equipment. They will, as a rule, be found willing and ready to cooperate and advise.

WHAT LUBRICATION MEANS TO THE BUILDER OF MACHINE TOOLS*

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ABSTRACT: Lubrication is an important part of a machine tool. It directly affects operational efficiencies and eventually its useful life. It should therefore be incorporated into original designs. The present paper reviews present-day lubrication requirements of such structural elements of machine tools as bearings, slides and gears.

This article presents a discussion of some of the problems associated with machine tool lubrication as seen through the eyes of the machine tool designer.

Successful lubrication of machine tools depends not only on the choice of suitable lubricants but also on satisfactory methods of application. It matters little how good a lubricant may be if provisions are not made to assure that it reaches the location where it is needed and when it is needed. Thus, lubrication of a machine tool actually begins with the designing engineer. He must be thoroughly familiar with those parts of the machine which must be lubricated, the general types of lubricants that are required, and the various methods by which they may be applied. Consequently, it is evident that the designing engineer plays a major role in the success or failure of machine tool lubrication. It is likewise apparent that he is in a very vulnerable position in this regard and frequently will be second-guessed not only by the ultimate purchaser and user of the machine and the lubricant vendors, but also by his own production and sales department.

Great strides have been made since the days when the machines were lubricated manually by means of the familiar oil can. Today there are many types of lubricating systems available, including the following: (1) Fully automatic systems of continuous lubrication so designed as to prevent machine operation until oil pressures have reached a predetermined level and lubricant is supplied to the machine. (2) Semi-automatic systems in which lubricant is supplied to the machine intermittently. (3) Manually operated single-shot systems. (4) Many varieties of sight-feed oilers, oil cups, etc.

The term "machine tool" does not refer to a specific machine or type of machine. On the contrary, it is used to describe a broad group of machines which includes many types and sizes. Machine tools may be very small, such as those used for inspection purposes, or they may be tremendous in size, as exemplified by some of the large planers, boring mills, and broaches. Feed rates will range from 1/16 inch per minute to as much as 400 feet per minute. Spindle speeds may be as low as one or two revolutions per minute or as high as 200,000 revolutions per minute on a high speed grinder. Regardless of the type or size of a machine tool and whether the job be a machining or measuring operation, it is expected to perform with an accuracy as great as a few ten thousandths of an inch (0.000x") or even ten millionths of an inch (0.00000x"). In selecting a lubrication system the designer must consider a number of factors, including the type of machine, the size, the operating conditions, and the service factors, together with the overall cost of the machine and the cost of the lubricating system. Invariably his ultimate choice will be, of necessity a compromise. In many instances the lubrication problems are specific for the individual machine tool involved. However, there are some lubrication problems which are more or less typical and on which it is possible to generalize.

Journal Bearings. Journal lubrication is seldom regarded as a serious problem today. This is due more to the great reduction in the use of journals during the past twenty years than it is to a reduction in the magnitude of the lubrication problem itself. With the advent and accelerated use of the rolling element (anti-friction) bearings, journals have currently been relegated to the category of the white horse. However, there are certain applications where the rolling element bearing has been found wanting and where journals still fulfill an essential need. One example is the work head of a very precise cylindrical grinder. The problem here is the production of an extremely smooth rotational device which turns in a perfect circle. Offhand these requirements do not appear to be too stringent but experience has shown that they can be very difficult to achieve. Generally the smooth characteristic desired can be realized with a good sleeve bearing, assuming that the driving mechanism itself does not introduce any irregularities. In operation the journal actually rotates on an oil film and rotation in a perfect circle depends on both an absolutely round journal and a uniform oil film. The lubrication problem is one of introducing the oil film and maintaining it at a constant thickness regardless of the load which might be imposed on the bearing. In this connection a machine tool designer must rely on the lubrication expert for assistance. If there were some simple and infallible means of solving this lubrication problem, it is likely that journals would be used much more extensively than they are.

Another application where journal bearings must be used is in a large sized machine where rolling element bearings will not permit the accuracy

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and the rigidity usually required in a machine tool. Examples are the table of a large vertical lathe or the work spindle of a thread miller or lathe.

Rolling Element Bearings. Rolling element bearings have proved to be a cure-all for the run-of-the-mine problem of supporting rotating shafts. Roller or ball bearings, either oil lubricated, grease packed or permanently sealed, can satisfy most of the requirements and their use has greatly reduced instances of seized bearings. However, there are still some applications where there is room for considerable improvement in both the bearing design and lubrication. This is particularly true for bearings that must operate at very high rotational speeds. Today it is not unusual for small bearings carrying spindles of internal grinding wheels to have speeds as great as 100,000 rpm. Below 30,000rpm there seems to be little or no lubrication problem. Above this speed however, there is much uncertainty as to whether satisfactory operation can be expected. This problem is not confined only to small bearings. Currently the large bearings used in milling machines are subject to high speeds in the milling of non-ferrous alloys used in the aircraft industry. In such operations the cutters will run at peripheral speeds of 3,000 to 5,000 feet/minute and require about 100 H. P. at 10,000 rpm. It is necessary that suitable provision be made for carrying the high radical loads and dissipating the high internal temperatures experienced.

Undoubtedly long bearing life would be realized if a proper film of lubricant could be maintained at all times during machine operation. Grease packed bearings or mist lubrication are both advocated and heated discussions can readily develop concerning the relative merits of each. In any event, the machine tool designer feels that the lubrication engineer has not yet provided a solution to the problem of high speed bearing lubrication which will assure satisfactory operation throughout the rated life of the bearing.

Consequently, the only current solution seems to be frequent replacement of the bearings and this is a problem in itself. In some cases the life of such bearings may be as short as 10 to 100 hours. The problem is one of deciding exactly when the bearings should be replaced. Should they be changed before evidence of deterioration appears, and if so, what should be used as a guide. All things considered, the problem of high rotational speeds presents a real challenge to both the bearing designer and the lubrication expert.

Sliding Ways. Another bearing lubrication problem cencerns the flat sliding ways commonly used on most machine tools. The operating requirements of these slides are quite stringent and vary over extremely wide limits. For example, in some machines the speed of travel over the ways is very low. The problem here is one of minimizing the variation between the static coefficient of friction and the sliding coefficient of friction so as to prevent uneven or jumpy operation of the slide. This is of particular concern in operations where ultra-high surface finishes are required. In other machines, the distance travelled over a slide is very small, perhaps of the order of one or two ten-thousandths of an inch and here the change in frictional forces presents a problem. When the system begins to move, any potential energy stored in the elastance of the driving members is suddenly released and the momentum may be sufficiently great to cause the moving part to overshoot its mark.

Cast iron and steel, both the soft and hard varieties, are the construction materials commonly used in these slide ways. The lubrication problem is one of preventing galling or welding throughout the wide range of speeds and loads encountered. These surfaces are frequently exposed to contamination by chips, coolants and dirt, and it is here more than at any other location on the machine that the greatest potential for wear and loss of accuracy exists. Scrapers may be employed to clean the slide ahead of the bearing and this procedure inevitably removes not only the contaminants present but also the lubricant as well. It is not uncommon for gouges or tears of an inch or more in cross section to be formed on a sliding way of a ten foot horizontal boring mill. Usually the blame is attributed to inadequate or incorrect lubrication, although this is not always the reason. However, there is no question but that slide way lubrication offers a fertile field for improving machine performance and reducing maintenance costs.

A relatively new and rather intriguing method of lubrication has been introduced during the past few years. It has been found that remarkably low coefficients of friction can be obtained by properly introducing and maintaining a film of air on the sliding surface of either a flat bearing or a journal. Remarkable results have been obtained on both journal bearings rotating at high speeds and with flat sliding ways. In the latter instance, coefficients of friction as low as 0.001 have been realized. Although this practice is used only occasionally at the present time in the machine tool industry, it is predicted that its application eventually will be very wide-spread.

Phenolic liners are frequently used on sliding ways and they have proved to be a god-send to the machine tool designer. Although they are not the answer to all of the problems of wear, friction, and accuracy, nevertheless they are not so dependent upon satisfactory lubrication as are the cast iron and steel surfaces. With the application of phenolic liners, complete failure of the lubricating system may occur and the machine still will continue to operate satisfactorily for a period of time during which it would normally be expected that the failure would be found and corrected. For example, the lubrication system on a rather large tracer-controlled milling machine operating 24 hours a day failed completely and a period of three days elapsed before the failure was spotted. During this time no lubricant was being supplied to the ways but there was no damage to this or any other portion of the machine. On the basis of past experience, it is almost certain that a disastrous failure would have occurred if the machine had been operated on cast iron to cast iron slides. It is equally certain that the machine would have been badly scored and a major overhaul and repair job would have been required. However, for reasons of space limitations, cost or accuracy, it is not always possible to use phenolic liners on a slide and fool-proof ways and means of lubricating these members are badly needed.

Miscellaneous Moving Elements. Many other lubrication problems connected with machine tools seem to be relatively simple. Gears, for example, are usually very easy to lubricate. Present types

can be readily enclosed in gear boxes and a suitable circulating oil system can be employed. Occasionally problems will develop with certain of the inefficient types of gears, such as worm drives or spiral gearing. However, the machine tool designer usually can impose relatively light loadings on these gears, since space and weight are not a limitation, and long life will result. The use of hardened or toughened gears, usually ground, also assist the designer in his lubrication problem.

Cutter Lubrication. After having provided for adequate lubrication of all moving parts on a machine tool, the designer finds that his job is still not complete. He must also provide a suitable system for supplying the cutting tools with coolants and cutting oils which assist them in their machining operations. Usually the distribution system itself can be relatively simple, although some of the newer methods of coolant applications, such as the Gulf-Thompson High-Jet and the use of carbon dioxide, will present certain problems if they should obtain wide-spread acceptance. However, in addition to providing a system for applying the coolant, the designer is also expected to advise the customer as to the type and kind of coolant or cutting oil he should use and the production and tool life that he should expect to attain.

Summary. Designing lubrication into a machine tool is the point that most designers become completely frustrated, and it is here that the designer may become rather critical of the lubrication engineers and the lubricant suppliers. When selecting something like a ball bearing, for example, data are available from each bearing manufacturer as to the size, fits, eccentricities, tolerances, load limits and expected life. From this information the machine tool designer can determine which bearings from one manufacturer are interchangeable with those of other manufacturers. Likewise, in purchasing a steel, it will be identified by the AISI member, or if it happens to be a special alloy, by an analysis. Furthermore, its hardenability, machining characteristics, modulus of elasticity and other physical properties will also be given. In selecting a pump for a hydraulic system, basic standard information on the volume displacement, pressure limitations, slippage and physical dimensions are available. In other words, practically all of the materials and component parts that are used in the construction of a machine tool are so standardized that manufacturers' equivalents are easily identified and recognized. However, this certainly is not the case with lubricants and cutting oils. These are usually identified by number, letters, catch words or any other means that appeals to the supplier. Since each lubricant manufacturer has his own pet names for his products, it is practically impossible for the machine tool designer to determine equivalent products from among the numerous manufacturers on the basis of the information available to him. It is felt that much can be done to standardize lubricants and cutting oils, not only from the standpoint of nomenclature, but also with regard to correlating the physical and chemical properties with practical applications.

Lubrication by and large does not represent an extraordinarily expensive portion of a machine but it does represent the difference between a mechanism having a long life with a minimum of maintenance and one giving frequent trouble and requiring considerable attention. Machinery i s becoming more complex every day and the importance of each of the component parts and their relation to each must be realized. The designer must be able to pass on to the users of the machines such vital information as will enable him to obtain optimum performance, and in fulfilling this task he must rely greatly on the lubrication engineer to furnish him with suitable lubricants and methods of application.

A·S·L·E LUBRICATION NEWS

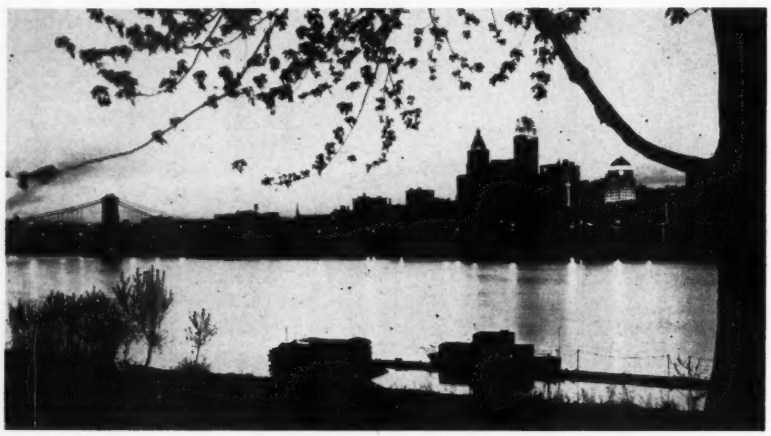
1954 ASLE ANNUAL MEETING & EXHIBIT
NETHERLAND PLAZA HOTEL, CINCINNATI, APRIL 5-6-7

PRESIDENT'S WELCOME, by W. E. Campbell. Another successful year for the American Society of Lubrication Engineers reaches its climax as you read these words, and brings me the pleasure of welcoming members of the Society and guests to its annual meeting here in Cincinnati.

The attendance at the numerous technical attractions which our Program Committee has planned for your enjoyment promises to be a record one. I hope that all of you will consider this welcome an individual introduction, and that anyone who needs help or advice will not hesitate to bring his problem to me or to a member of the board. Your Society is anxious to be of help because service is its watchword at all times — service to Industry by promotion of improved maintenance and longer life for equipment, service to Science and Engineering by stimulating publication of technical information, and service to Society in working towards the advancement of technical education. This meeting aims to achieve these purposes by giving each one of you the maximum possible benefit from attendance both in technical education and in social relaxation between technical sessions.

A rich variety of technical information is available in the many concurrent sessions, ranging from basic discoveries fresh out of the laboratory, to practical hints discussed in numerous panel sessions by plant men who are literally helping to grease the wheels of progress. We invite your active participation in as many of these sessions as meet your needs.

In addition to the technical sessions and panel discussions, our Annual Exhibit of the products of the lubricant manufacturers, of lubricants application equipment, and of other products relating to activities of the lubrication engineer, will be on display, enabling the lubrication engineer to keep up-to-date with the latest developments in his profession. Also, meetings of the various technical and education committees will be held during the evenings. These are not restricted, but are open to all who are interested.



Night Skyline of Cincinnati, Ohio.

This year a new service has been provided for members and their guests in the form of an Education Course to provide coverage of the basic needs of a maintenance engineer concerned with lubrication, during the three days of the meeting.

The Cincinnati Annual Meeting Committee, through its Ladies Program Committee, has outdone itself in providing a social program for the ladies during the day which will help to make their stay in Cincinnati a memorable one.

I wish to express my appreciation and thanks to the large army of interested members which has worked so unstintedly to make this meeting a success and to smooth my path during the past year. The continuing vigorous growth of our young Society is testament to the success of their efforts.

IN APPRECIATION. We, of the Cincinnati Annual Meeting Committee, wish to express our many thanks to the Boston, Philadelphia, and Cleveland Sections for all the help extended to us so willingly. Your counsel and guidance was a great help in setting up our committees and planning our program.

Also we wish to thank the chairman and members of our good neighbor section in Dayton for their fine cooperation. The active help given to all our committees has lightened our burden very much and is gratefully appreciated. Likewise the help and guidance of the National Officers, and in particular the guidance of Bill Youngclaus. We will be only too glad to pass along to the Chicago Section any help tht we can in their preparation for the 1955 meeting.

WELCOME TO CINCINNATI, by C. C. Weymiller, Chairman of the Cincinnati Section. The Cincinnati Section is indeed pleased to welcome you to the 9th Annual Meeting of the American Society of Lubrication Engineers. We consider it an honor to be host Section and sincerely hope that your visit will result in long and pleasant memories of Cincinnati.

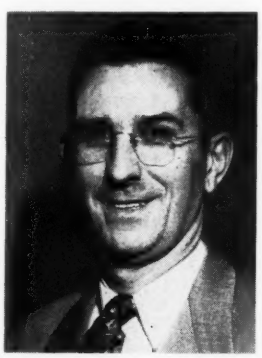
Since the results of nearly a full year's hard work on the part of the Annual Meeting Committee will be described elsewhere, it seems pertinent to furnish a brief history of the Cincinnati Section and also the highlights of the City of Cincinnati history.

The Cincinnati Section was organ-

ized in the spring of 1950 with Bill Cornelius, Gene Merchant, Chet Garrison, Guy Peters and Bill Whalen providing the spadework necessary in obtaining members and affiliation with the Society. Since that time we have grown to a membership of fifty-five with thirteen sustaining members. Our meetings are normally held at the headquarters of the Engineering Society of Cincinnati. We are one of twenty-four organizations comprising the Technical and Scientific Societies Council of Cincinnati. Our membership is well balanced between engineers engaged in lubricant sales, dispensing equipment sales and plant maintenance. This group comprises the nucleus of those engaged in lubrication in the Cincinnati area.

Cincinnati, the Queen City, was founded in 1788 and quickly established itself as the gateway to the south and west due to its geographical location. The city rises on a low terrace on the banks of the Ohio river and is surrounded by seven hills which are the residential districts. The population is approximately a half-million and greater Cincinnati embraces over a million people. Cincinnati is the cultural center of the Midwest with the College of Music, Symphony Orchestra, Xavier University, and the University of Cincinnati fulfilling major roles. Cincinnati has outstanding parks, museums and an excellent zoo. While industry is widely diversified, Cincinnati is a leader in the machine tool, brewery, soap and meat packing industries. Politically Cincinnati is recognized as one of the best governed cities and employs the City Manager form of government.

Cincinnati has everything prepared for you to enjoy your visit, from your arrival in our Union Terminal to pleasant shops and stores, ultra modern hotels, the Annual Meeting Program and the Ladies Program. We hope your visit will be most enjoyable.



WELCOME FROM CINCINNATI ANNUAL MEETING COMMITTEE, by W. D. Whalen, Chairman. This is the day we have been looking forward to for many months. It is indeed a very pleasant privilege that we of the Cincinnati Section have of being host to the Annual Meeting of the American Society of Lubrication Engineers. We hope and believe that this will be the largest and best annual meeting held to date.

Our committees have worked untiringly preparing for this meeting. We want you to know that our entire committee is at your service and will try to make your attendance at this meeting enjoyable and profitable to you in your work-a-day lives.

For the Monday luncheon, which officially opens this meeting, we will have a very colorful baseball figure and world traveler as toastmaster. A newspaper columnist of world renown will be guest speaker.

We sincerely believe that the National Program Committe has prepared an outstanding technical program. We are proud that they have chosen to inaugurate, at this meeting, a lubrication engineering course for plant personnel and others who may wish to learn more of the basic fundamentals of lubrication. While a very complete program has been prepared, we do hope that you may find some time to tour our city and enjoy some of the scenic beauty of the city of "Seven Hills."

To all the ladies who have come to visit our fair city we extend a special welcome. An outstanding program has been prepared to entertain you and acquaint you with the art, the industry and the grandeur of Cincinnati.

We sincerely want you all to enjoy the hospitality of Cincinnati and to feel as you leave at the end of the meeting that you have been richly rewarded for your attendance.

WELCOME TO THE VISITING LADIES, by Mrs. M. E. Merchant, Chairman of the Ladies Program Committee. The Cincinnati Section of ASLE welcomes the wives and guests of members attending the Annual Meeting in Cincinnati. A program has been planned for your entertainment which we sincerely hope will make your visit to our city interesting and delightful.

Following registration on Monday morning, the Ladies Group will be conducted on a tour through the Terrace Plaza . . . truly one of America's most modern hotels. Luncheon will be served in the beautiful Skyline Restaurant which commands a superb view of the Ohio Valley.

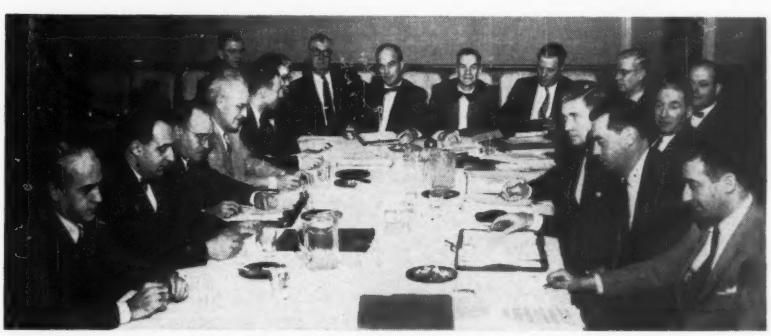
The afternoon program should be of interest to everyone. The early part of the afternoon will be spent in the studios, workrooms and galleries of the Rookwood Pottery, located on the picturesque summit of "Old World" Mt. Adams, overlooking downtown Cincinnati. The group will be permitted to watch the skilled artisans demonstrate the techniques which make this fine pottery one of Cincinnati's contributions to the fine arts.

The day's program comes to a close with a visit to the Krohne Floral Conservatory to view the yearly Easter exhibit, featuring not only the flowers typical of this time of year, but the permanent rare orchid display.

Inasmuch as the Committee has endeavored to show ASLE visitors the top industrial and art exhibitions of Cincinnati, for which the city is world famous, the Tuesday program will get underway with a tour through The Baldwin Piano Co. Here, the group will see how the ivory and ebony from Central Africa, the gums and resins from India, the fine wood from Honduras and Ceylon, and the, approximately, 6,000 parts of a Baldwin Piano are finally built, tested and shipped.

Feeling that the Ladies Group might like a brief trip "South of the Border," arrangements have been made to have the ladies served luncheon at The Hearthstone on the Dixie Highway, a few miles south of Covington, Kentucky. En route to the restaurant, a visit will be made to St. Mary's Cathedral, one of the finest examples of ecclesiastical Gothic architecture in America. Modeled after famous Notre Dame of Paris, it contains the largest stained glass window in the world and murals and sculptured groups by Frank Dubeneck, nationally known artist and native of Covingtonian.

Another highlight of the Tuesday program will be the opportunity to visit the Procter & Gamble factory, to observe the manufacture of soaps, synthetic detergents and vegetable shortenings. The tour will begin with a slide film presentation which quickly reviews the Company's history, the scope of its operations, and gives a brief description of the major soap-making processes. Visitors are then taken on a conducted tour of the factory where they will see some of America's best known products . . . Ivory Soap, Camay, Duz, Joy, Crisco, and others . . . being made and packaged. Following the tour, the wives of ASLE will receive a gift as-



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Knowledge of the lubricant capacity of a bearing need not rely upon mathematical or theoretical calculations. Injector Valves are externally adjustable to accurately deliver *the exact quantity* of lubricant required by each bearing.

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The pumping unit forces lubricant to all bearings in the system, simultaneously, at the specified time interval by means of the selective setting of the pressure developed by the central pump.

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A bearing lubricant film can be maintained constantly by the control possible in timing the frequency of lubricant replenishment.

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Contamination of lubricant is eliminated when dispensing from an original refinery container or self-contained reservoir through the sealed injector circuit, direct to the bearing.

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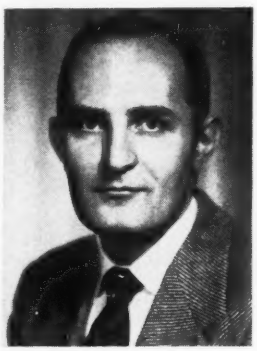
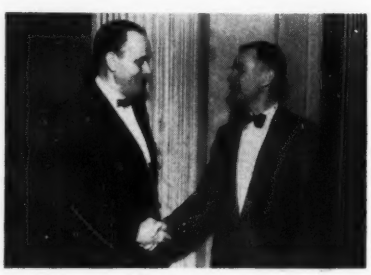
Wednesday morning has been left open for those who may wish to shop, etc.; however, if sufficient interest is shown in a trip to the Taft Museum, arrangements will be made to take the group to this outstanding art exhibit, gift of the Taft family to the City of Cincinnati.

The 9th Annual Meeting comes to a close Wednesday afternoon with a visit to Crosley Square Television Studio. The ASLE ladies will visit and may participate in a TV show, "Pick A Pack Of Prizes."

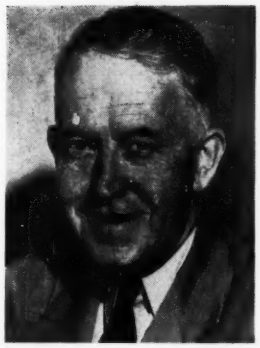


THE TRANSISTOR, by Morgan Sparks, guest speaker of the Annual Banquet. A tiny crystal of a long neglected material has been found capable of performing amazing feats in the mushrooming field of electronics. This new tool, called a transistor, is destined to become important in our daily lives as well as opening new horizons in such technical fields as communications, computers, and automation of factories. A popular description of what a transistor is and how it works will be given. The transistor requires fantastically pure germanium, an element with very unusual properties, but of no usefulness until very recently. The story of the purification of this material, which is a semiconductor, will be briefly told. There will be demonstrations of a few applications of transistors.

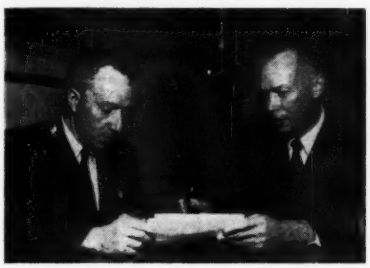
(Mr. Sparks was born in Pagosa Springs, Colorado. He received a B.A. degree from the Rice Institute in 1938, and an M.A. from the same institution in 1940. He was aRockefeller Foundation Fellow at the University of Illinois where he received a Ph.D. in Physical Chemistry in 1943. He joined the Bell Telephone Laboratories in the field of electrochemistry, and since 1948 has been engaged in solid state research related to the transistor.)



Retiring President, W. E. Campbell (right) congratulates J. Boyd, President-Elect.

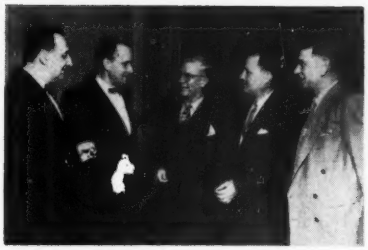


NIXON DENTON, a noted war correspondent in World War II and in the Korean War, will be the feature speaker for the Monday noon luncheon. Mr. Denton started his newspaper career in 1915 in Muskogee, Oklahoma, when oil was oil (before Tulsa moved in on the picture). He served in the first World War and after the war moved to Louisville, Kentucky, and became Sunday Editor of the Courier Journal. For the past 30 years, Mr. Denton has been popular Sports Editor of the Cincinnati Times Star. His philosophical daily column, "Second Thoughts," is widely read.



Dayton representatives of Annual Meeting Committee: V. C. Hutton, Chairman (left); and A. H. Turner, Vice-Chairman.

Joint meeting of the Program and Annual Meeting Committees. Pictured (from left to right, front row) are: D. W. Sawyer, representative of the Technical Committees; J. L. Finkelmann, Vice-Chairman of the Program Committee; A. E. Baker, Jr., Board of Directors, and sponsor of the Program Committee; J. J. O'Connor, Chairman of the Program Committee; W. D. Whalen, Chairman of the Annual Meeting Committee; (back row) W. H. Cornelius, Annual Meeting Committee; R. H. Josephson, Board of Directors, and last year's Program Committee Chairman; A. E. McGee, Annual Meeting Committee.



John Boyd "talks it over" with some of the Officers and Directors. Pictured (from left to right) are: W. C. Kesler, Director; J. Boyd, President-Elect; W. H. Fowler, Jr., Secretary-Treasurer; W. M. Schuck & G. Findlay, Directors.

1954 Annual Meeting Committee. Pictured (from left to right, front row,) are: A. E. McGee; W. D. Whalen, Chairman; Mrs. M. E. Merchant; M. E. Merchant; C. C. Weymiller, Chairman of the Cincinnatti Section; (back row) I. C. Smith; A. L. Hartley; G. Peters; C. A. Garrison; A. L. Janke; W. H. Cornelius.

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1. MECHANICAL ENGINEER, preferably with training in hydro-dynamic lubrication theory.
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Applicants should be 25-30 years of age, should have had a few years of research experience, preferably in industry, and have demonstrated independence and initiative.

This will be long term research, divorced from immediate development problems, with excellent opportunities for advancement. Employees are covered by group life and health insurance, contributory pension plan.

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WAITE HOYT, Toastmaster for the Monday luncheon, is well known as Television Sports Broadcaster on Cincinnati TV Station WCPO and for his brilliant baseball career from 1915 to 1938. Mr. Hoyt has established a number of "firsts" in his colorful contributions to baseball history. At 15 years of age, when he joined the New York Giants as batting practice pitcher, he was the youngest boy ever to sign a major league contract. In 1921, he tied Christy Mathewson's existing record of no earned runs in three complete World Series Games when he pitched for the New York Yankees against the Giants for the Yankee's first Major League Championship. His radio career began in 1927 but became his major vocation on his retirement from baseball. In 1949, he became the first baseball broadcaster to broadcast baseball simultaneously over television and radio.

Executive Committee goes into a huddle with Administrative Secretary of ASLE as the big date nears. Pictured (from left to right) are: M. E. Merchant, Chairman of the Presidential Council; W. E. Campbell, President of ASLE; W. P. Youngclaus, Jr., Administrative Secretary; J. Boyd, President-Elect and Vice-President at Large; W. H. Fowler, Jr., Secretary-Treasurer.

The four Regional Vice-Presidents "compare notes" on their respective territories. Pictured (from left to right) are: M. E. Dougherty, Eastern; J. W. Hopkinson, Midwestern; T. A. Marshall, Canadian; P. S. Adams, Western.

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PROGRAM

1954 ASLE ANNUAL MEETING & EXHIBIT

MONDAY, APRIL 5, 1954

8:00 AM **REGISTRATION,** Fourth Floor Foyer

TECHNICAL SESSIONS FEES: Members $3.00; Non-Members $5.00 of which $2:00 may be credited towards membership in the Society if application is made within thirty days after the Annual Meeting.

LUBRICATION ENGINEERING COURSE FEES: Members $10.00; Non-Members $15.00. This registration fee covers the five Sessions in the Lubrication Engineering Training Course to be held concurrently with the Technical Sessions and gives all such registrants the full privileges accorded the Technical Sessions Registrants.

EXHIBIT REGISTRATION: The Exhibit area is open to all registrants without charge, and is open to all visitors who register.

9:00 AM **OFFICIAL OPENING OF EXHIBITS,** Hall of Mirrors.

11:00 AM **ANNUAL BUSINESS MEETING,** South Meeting Hall; Chairman: W. D. Whalen, R. K. LeBlond Machine Tool Co.

President's Message: W. E. Campbell, Brush Labs. Co., Div. of Clevite Corp.

12:30 PM **CINCINNATI SECTION WELCOME LUNCHEON,** Pavilion Caprice

2:15 PM **Session 1-A RECLAMATION OF INDUSTRIAL PETROLEUM PRODUCTS (Panel Session)** Chairman: D. L. Richards, Carlisle Chemical Works

Filters, their Function and Application, by J. R. McCoy, Honan-Crane Corp.

Reclamation of Industrial Petroleum Products, by C. H. Palmer, Diesel Equipment Div., GMC

Centrifuges — Their Functions & Applications, by K. D. Reed, The DeLaval Separator Co.

Reclamation of Used Wash Solvents, by J. H. Hills, Hills & Morrow, Inc.

Session 1-B RAILROAD BEARINGS, Chairman: G. M. Robinson, Franklin Institute

Roller Bearings for Railroad Equipment, by R. J. Brittain, Hyatt Bearings Div., GMC

Solid Type Bearing in Railroad Freight Service, by E. S. Pearce, Railroad Service & Supply Corp.

Comments of Laboratory Compatibility Testing of Lubricating Greases, by H. C. Zweifel, Richfield Oil Corp.

Session 1-C FUNDAMENTALS OF LUBRICATION, Chairman: E. R. Booser, General Electric Co.

Frictional Properties of Soaps at High Pressures, The, by J. R. White, Socony-Vacuum Laboratories

Boundary Friction of Very Well Lubricated Surfaces, The, by E. Rabinowicz, Massachusetts Institute of Technology

Limiting Bulk Fluid Temperatures for Effective Boundary Lubrication by Synthetic Lubricants, by S. F. Murray, R. L. Johnson, & E. E. Bisson, NACA Lewis Flight Propulsion Lab.

Synthetic Lubricants for Aircraft, by J. King, H. Schwenker, & J. C. Mosteller, Wright Development Center

Lubrication Engineering Course, Session 1 Leaders: W. E. Campbell, Brush Labs. Co., Div. of Clevite Corp., & D. D. Fuller, Columbia University

6:00 PM **EQUIPMENT & PRODUCTS DISPLAY** Exhibits open to visitors until 10:00 PM

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TUESDAY, APRIL 6, 1954

9:00 AM **Session 2-A LUBRICATION APPLICATION PROBLEMS AND THEIR SOLUTION IN THE COAL INDUSTRY (Coal Panel)** Chairman: G. R. Spindler, University of West Virginia

W. S. Fuhr, Hanna Coal Co.; W. R. Wood, Berwind-White Coal Co.; J. J. Slomer, Goodman Mfg. Co.; G. C. Delmaso, Joy Mfg. Co.; F. C. Robert, Gulf Oil Co.; C. J. Moser, The Texas Co.

Session 2-B FUNDAMENTALS OF LUBRICATION Chairman: M. E. Merchant, The Cincinnati Milling Machine Co.

Behavior of Sleeve Bearing Materials, The, by C. M. Allen & K. A. Davis, Battelle Memorial Institute

Surface Active Rust Preventives in Lubricating Oil, by D. W. Criddle, California Research Corp.

Coefficient of Friction and Damage to Contact Area During Early Stages of Fretting, by D. Godfrey & J. M. Bailey, NACA Lewis Flight Propulsion Lab.

Session 2-C GENERAL INDUSTRY I Chairman: R. R. Slaymaker, Case Institute of Technology

How to Put Across a Technical Paper, by L. N. Rowley, Power Magazine

Industrial Plant Disposal Problems and their Solution, by J. W. Townsend, Consoer-Townsend & Associates

Planned Lubrication as a Part of Preventive Maintenance at Cadillac, by A. C. McKeen, Cadillac Motor Car Div., GMC

Lubrication Engineering Course, Session 2 Leader: C. A. Bailey, National Tube Div., U. S. Steel Corp.

2:15 PM **Session 3-A FUNDAMENTALS OF LUBRICATION** Chairman: A. E. Baker, General Electric Co.

Study of Fretting Corrosion, A, by E. E. Weismantel, Westinghouse Electric Corp.

Thin Film Lubrication, by D. D. Fuller, Columbia University (presenting translation)

Reaction of Adsorbed Stearic Acid with Copper & Copper Oxide, The, by A. Dobry, Westinghouse Electric Corp.

Session 3-B BEARING DESIGN TODAY Chairman: A. E. Roach, Research Labs. Div., GMC

Bearing Practice on Large Rotating Electrical Machines, by B. B. Winer & R. A. Baudry, Westinghouse Electric Corp.

Engine Bearing Design Today, by J. B. Bidwell, General Motors Research Labs.

Measured Oil Film Pressure Distribution in Misalined Plain Bearings, by F. W. Ocvirk, Cornell University

Session 3-C METALWORKING Chairman: W. C. Whitson, R. T. Whitson & Son

Laboratory Test for Evaluation of Metal-Forming Lubricants, A, by R. S. Barnes & T. H. Cafcas, Standard Oil Co. (Ind.)

Lubrication Engineering Course, Session 3 Leader: R. J. Torrens, Eastman Kodak Co.

6:30 PM **COCKTAIL PARTY & ANNUAL BANQUET** (Dress Informal)

WEDNESDAY, APRIL 7, 1954

9:00 AM **Session 4-A LUBRICATION APPLICATION PROBLEMS AND THEIR SOLUTION IN THE STEEL INDUSTRY (Steel Panel)** Chairman: T. A. Marshall, Steel Co. of Canada, Ltd.

C. A. Bailey, U. S. Steel Corp.; C. T. Lewis, Republic Steel Co.; H. H. Wood, Morgan Construction Co.; B. J. Lamport, United Engrg. & Fuel Co.; G. H. Davis, Shell Oil Co.; M. S. Clark, The Texas Co.; G. D. Jordan, United Steel Ltd.; England; W. J. Polny, Loewy Construction Co., Inc.

Session 4-B METALWORKING Chairman: J. O. McLean, Reynolds Metals Co.

Wire Drawing Lubricants — From Raw Material to Finished Compounds, by L. Salz, Magnus Chemical Co., Inc.

Lubrication of Die Forging Presses, by R. G. Sturm, Alabama Polytechnic Institute

Fluids for the Grinding of Titanium, by E. J. Krabacher, The Cincinnati Milling Machine Co.

Wax Coolants & Heat Dispersion, by F. C. Kraatz, S. C. Johnson & Son, Inc.

Session 4-C PHYSICAL PROPERTIES OF LUBRICANTS Chairman: M. L. Langworthy, The Texas Co.

Microchemical Techniques in the Diagnosis of Lubrication & Wear Problems, by W. E. Campbell, Brush Labs. Co., Div. of Clevite Corp., and H. V. Wadlow, Bell Telephone Laboratories

X-Ray Spectroscopy in the Analysis of Lubricating Oils, by R. A. VanNordstrand & E. N. Davis, Sinclair Research Labs., Inc.

Spectroscopy Applied to Analysis in the Petroleum Industry, by R. C. Pomatti, R. F. Meeker, & H. Levin, The Texas Co., Beacon Labs.

Lubrication Engineering Course, Session 4 Leader: W. T. Everitt, Eastman Kodak Co.

2:15 PM **Session 5-A OIL SEALS (Panel Session)**

Fabric Packings, by D. S. Missenger, Garlock Packing Co.

Homogenous Rubber Packings, by J. A. Swartz, Linear Inc.

Leather Packings, by H. Blair, E. F. Houghton & Co.

Face Seals, by C. E. Schmitz, Crane Packing Co.

Session 5-B SYNTHETIC LUBRICANTS CLINIC Chairman: W. T. Meinert, Emery Industries

W. H. Ragborg, Dow Corning Corp.; W. H. Millett, Carbide & Carbon Chemicals Co.; F. Hardy, Bell Telephone Labs., Inc.; D. H. Moreton, Douglas Aircraft Co.; V. W. Ware, Rohm & Haas Co.

Session 5-C GENERAL INDUSTRY II Chairman: N. C. Penfold, Southwest Research Institute

Engine Lube in Taxicab Service, by O. W. Wuerz, Cab Service & Parts

Foaming of Heavy-Duty Lubrication Oil, by L. M. Tichvinsky & W. M. Pugh, University of California

Static Water Drop Corrosion Test, by E. J.

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Schwoegler & L. U. Berman, Armour Research Foundation
Lubrication Engineering Course, Session 5
Leader: K. S. Smiley, E. I. duPont deNemours & Co.

2:15 PM BUSINESS MEETING OF ASLE OFFICERS & DIRECTORS

LADIES PROGRAM

SUNDAY, APRIL 4, 1954

2:00 PM Early Registration, Julep Room

MONDAY, APRIL 5, 1954

8:00 AM Registration, Julep Room

10:30 AM Group leaves Netherland Plaza Hotel (Julep Room) for tour through new Terrace Plaza Hotel.

12:00 N Luncheon, Skyline Room, Terrace Plaza Hotel.

1:30 PM Bus leaves Terrace Plaza Hotel for afternoon tours.

2:00 PM Tour of Rookwood Pottery atop Mt. Adams.

3:00 PM Visit to the Krohne Floral Conservatory to view the Easter exhibit.

4:00 PM Return to Netherland Plaza Hotel.

TUESDAY, APRIL 6, 1954

9:00 AM Bus leaves Netherland Plaza Hotel to visit and tour the Baldwin Piano Co. plant.

9:30 AM Tour of plant (to 11:00 AM).

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12:00 N Luncheon at The Hearthstone on the Dixie Highway outside of Covington, Kentucky; transportation by bus from the Baldwin plant.

1:00 PM Bus leaves restaurant and returns to Cincinnati, where a brief scenic tour will be made of the city en route to Procter & Gamble Co. at Ivorydale.

2:00 PM Tour of the Procter & Gamble Plant.

3:30 PM Return to Netherland Plaza Hotel.

WEDNESDAY, APRIL 7, 1954

Wednesday morning has been left open for those who may wish to shop, etc.; however, if sufficient interest is shown in a trip to the Taft Museum, arrangements will be made to take the group to this outstanding art exhibit.

2:00 PM Group leaves Netherland Plaza Hotel to attend television show at Crosley Square Television Studio.

2:30 PM TV show, "Pick A Pack Of Prizes."

3:15 PM Return to Netherland Plaza Hotel.

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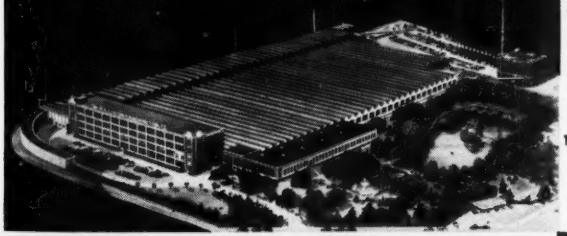

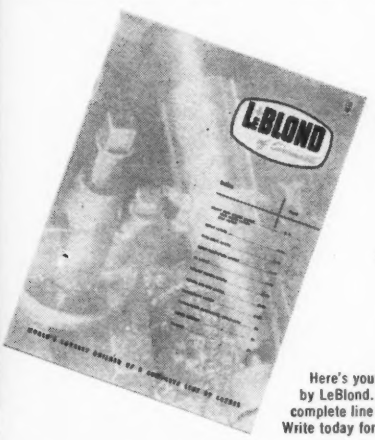

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Annual Meeting Authors

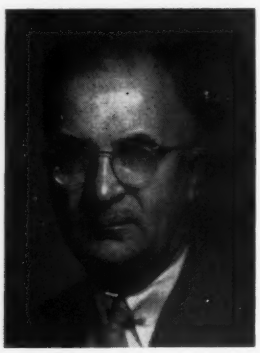
Authors of papers to be presented at the 9th ASLE Annual Meeting, Netherland Plaza Hotel, Cincinnati, April 5-6-7.

Abstracts of papers follow, except for those arriving too late to meet publication deadlines. They do not necessarily represent the final opinions of the authors and are subject to revision when the complete papers are published.

C. M. Allen

C. A. Bailey

R. S. Barnes



R. A. Baudry

L. U. Berman

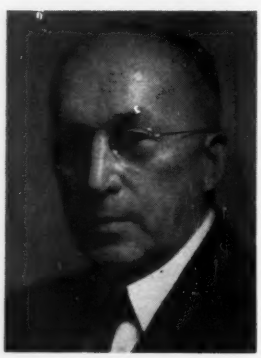
J. B. Bidwell

E. E. Bisson

R. J. Brittain

T. H. Cafcas

W. E. Campbell



M. S. Clark

D. W. Criddle

E. N. Davis

G. H. Davis

K. A. Davis

G. C. Delmaso

W. S. Fuhr

D. D. Fuller

D. Godfrey

F. Hardy

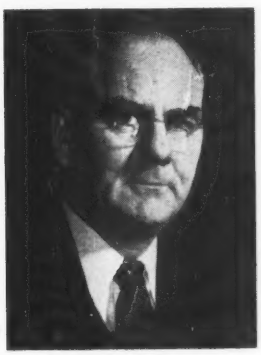
J. H. Hills

R. L. Johnson

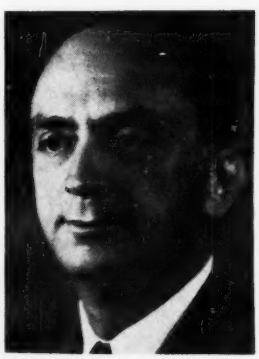
G. D. Jordan

F. C. Kraatz

E. J. Krabacher



B. J. Lamport



H. Levin

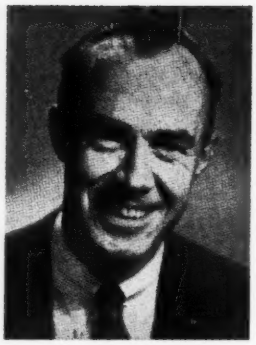
C. T. Lewis

J. R. McCoy

A. C. McKeen

R. F. Meeker

W. H. Millett



D. H. Moreton

C. J. Moser

C. H. Palmer

R. C. Pomatti

E. Rabinowicz

W. H. Ragborg

K. D. Reed

F. C. Robert

L. N. Rowley

L. Salz

C. E. Schmitz

E. J. Schwoegler

J. J. Slomer

L. M. Tichvinsky

J. W. Townsend

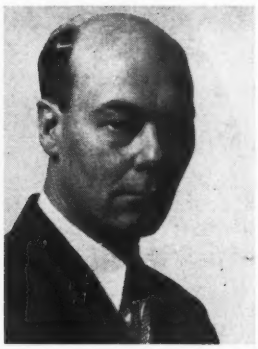
R. A. VanNordstrand

H. V. Wadlow

V. W. Ware

B. B. Winer

H. H. Wood



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Annual Meeting Abstracts

The following abstracts of papers to be presented at the 1954 ASLE Annual Meeting, Netherland Plaza, Cincinnati, April 5-6-7, are published herewith for general information and to stimulate discussion at the meeting.

Aircraft Industry Views Synthetic Lubricants, The, by D. H. Moreton, Douglas Aircraft Co.

One of the first industries to press petroleum lubricants to and beyond their maximum limits in several physical and chemical characteristics, the aircraft industry has already recognized some of the advantages of synthetic lubricants and has similarly experienced some of the problems involved in their use. The advantages of the synthetics require very little review from our industry, since in most cases the requirements have dictated their selection over petroleum products. Their proper adaption to men and machines designed largely for petroleum products is the phase of this problem which has demanded most of our consideration thus far.

Behavior of Sleeve Bearing Materials, The, by C. M. Allen & K. A. Davis, Battelle Memorial Institute.

In an earlier paper, sleeve bearing test data were given showing that pure copper behaved surprisingly well as a bearing material under a variety of test conditions. These results conflicted with commonly held opinions, so additional work was done to determine the effect of other testing variables on the bearing behavior of copper. Copper was found to behave better than conventional bearing materials, except when run against a soft shaft using a dirty oil simultaneously. A dirty oil did not have an adverse effect with a hard shaft. Field trials of copper bearings, using hard shafts would seem to be desirable.

Boundary Friction of Very Well Lubricated Surfaces, The, by E. Rabinowicz, Massachusetts Institute of Technology.

The frictional resistance to sliding of boundary-lubricated metal surfaces is made up of two main parts, one corresponding to shear within the lubricating film, the other to interaction between the metal surfaces resulting from metallic contact through the penetrated lubricant layer. Calculations suggest that in the presence of good lubricants such as copper palmitate this latter effect may be small, and in this case it follows that the coefficient of friction is to a very large extent determined by the rheological behaviour of the lubricant film and little influenced by the nature of the solid surfaces. Experiments are described to investigate this view. Accurate measurements of the friction coefficient have been carried out for various combinations of metals, using a geometry giving localized contact. As long as the same softer metal was used and thus the pressure was constant, the coefficient of friction was found to be nearly independent of the nature of the harder metal. Hence it became possible to measure the frictional properties of the lubricant, and the way these properties were affected by pressure and velocity, without reference to the nature of the surfaces. The close analogies of this system with friction in the full-fluid region are discussed.

Centrifuges — Their Functions & Applications, by K. D. Reed, The DeLaval Separator Co.

The function of a centrifuge is primarily that of separating immiscible liquids of different specific gravities and also the removal of sediment and other foreign matter from them. Among the principle applications of centrifuges in industry are the purification of turbine oil, insulating oil, hydraulic oils, fuel oil, diesel engine lubricating oil, and lubricating oils or coolants for steel, aluminum, copper, brass, rubber and paper mills, the clarification of grinding coolants and cutting oils and the reclamation of various factory oils such as those used for engine block tests, run-in oils and other similar applications.

Coefficient of Friction and Damage to Contact Area During Early Stages of Fretting, by D. Godfrey & J. M. Bailey, NACA Lewis Flight Propulsion Lab.

Experiments were conducted to measure the coefficient

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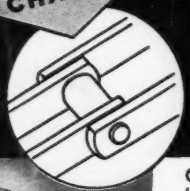

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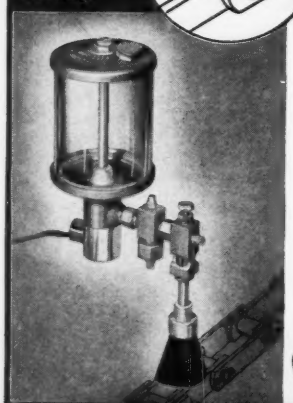

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of friction μ and to determine the damage to the contact area during early stages of fretting of copper at a frequency of 5 cycles per minute. Specimen combinations of copper against glass, copper against copper, and copper against steel, as well as various copper oxide films and powder compacts, were used. The results lead to the conclusion that fretting of copper starts with the same mechanical damage that occurs during unidirectional sliding. Fretting of copper against glass, copper against copper, and copper against steel starts with adhesion and metal transfer (galling) with accompanying high μ valves the same as those obtained during unidirectional sliding. After the initial high values of μ, a reduction in μ was observed, associated with reduced plowing and an increasing concentration of debris in and around the contact area. After approximately 100 cycles of fretting, μ reached a constant value (0.5-0.6) approximately the same as that obtained with compacts of either cuprous or cupric oxide. The presence of preformed cuprous or cupric oxide films on copper does not delay the occurrence of fretting but only lowers the initial coefficient of friction.

Comments of Laboratory Compatibility Testing of Lubricating Greases, by H. C. Zweifel, Richfield Oil Corp.

Compatibility studies of lubricating greases involve certain phenomenon that are critical in laboratory testing. These phenomenon are difficult to evaluate in terms of the functioning of the lubricant or mixture of lubricants in railroad roller bearing car journals. Sampling techniques complicate the study of these phenomenon when evaluating lubricating greases under test in full scale laboratory or road performance tests.

Engine Bearing Design Today, by J. B. Bidwell, General Motors Research Laboratories.

Bearings are only one consideration in a complete engine design and compromises are frequently necessary to achieve a durable and efficient product. The engine designer generally places strict limitations on the geometry of the bearings. It then becomes the job of the bearing engineer to make the best use of the space by careful selection of materials, lubricant supply and clearance. This selection must consider the loading condition, structural deflections, operating temperatures, lubricant, and manufacturing tolerances. Current research in engine bearings is aimed primarily at two characteristics of bearing materials: fatigue and scoring. Some progress has been made toward a fundamental understanding of these phenomena.

Fluids for the Grinding of Titanium, by E. J. Krabacher, The Cincinnati Milling Machine Co.

The grinding fluid is presently the most important factor controlling the effectiveness of the titanium grinding operation. This paper presents an analysis of the fundamental factors which contribute to the many difficulties experienced in the grinding of titanium. This analysis, based on findings of research into the machining of titanium, suggests possible approaches to the solving of these problems. The development of an effective grinding fluid is found to be the most direct approach. Steps taken in the development of such a fluid are presented along with substantiating experimental data.

Foaming of Heavy-Duty Lubricating Oil, by L. M. Tichvinsky & W. M. Pugh, University of California.

Foaming of lubricating oils present a comparatively new problem for a designing engineer. During and since the last world war most of Diesel engine lubricating oils approved by the U. S. Navy and other governmental agencies were required to contain various types of additives due to which it was possible to obtain high engine performance. It was found, however, that some of these essential additives caused the oil to foam at operating temperatures of the engines. Foaming tendencies of even straight mineral lubricating oils are also increased during present day high-altitude flying in rarefied air. Modern automobile hydraulic systems cannot tolerate any appreciable amount of air-oil foams. Fortunately, a very effective anti-foam agent was discovered which permitted the use of additives without deleterious foaming and thus enabling to maintain high engine output. As a result of the above considerations a new test method for the evaluation of foaming tendencies of lubricating oils has been evolved and incorporated in standard specifications.

The present paper describes a series of tests performed with the use of an apparatus constructed in accordance with the above bubbling method. All experiments were conducted

with lubricating oils of SAE 50 viscosity rating. Results indicate that great variation may be expected in conducting such tests on account of the many variable parameters influencing foaming and on account of insufficient description of test procedures. For comparative purposes and for obtaining sufficiently reproducible foam test data with the use of the bubbling method, the rate of circulating air should be specified and regulated very closely. Variation of the bath temperature, it was found, should not exceed plus-or-minus 1/2 degree Fahrenheit. Because of differences in the permeability of the porous plugs used in the method, it is recommended that they be first calibrated in order to select plugs of the same characteristics for a series of tests. It is also stressed that the rate of foaming of a used oil is considerably higher than that of new oil and depends on the extent to which it was previously aerated as well as the temperature of such aeration.

Frictional Properties of Soaps at High Pressures, The, by J. R. White, Socony-Vacuum Laboratories.

Soaps are employed as lubricants both directly as in greases, die lubricants, and cutting fluids and, indirectly, as products of reaction between lubricated surfaces and acid or partial ester type addition agents contained in lubricating oils. A significant property possessed by soap lubricants is their ability to yield under application of low shearing stresses even when normal (compressive) stresses are high. Thus soaps possess the property of allowing load bearing surfaces to slide easily. To understand better these frictional properties of soaps, the shear strengths of the series of even carbon number sodium fatty acid soaps from C_6 to C_{18} have been measured over the normal pressure range of 35,000 psi to 240,000 psi and over the temperature range of 27 C., to 125 C. Miscellaneous iron and partial phosphate soaps have also been measured. Generally, at the lower normal pressures, 35,000 to 68,000 psi, soaps exhibit increasing shear strength with decreasing carbon chain length. At the higher pressures, 160,000 to 240,000 psi, the shear strengths vary little with carbon chain length. At all pressures, the shear strengths decrease with increasing temperature in range of 27 C., to 100 C. At temperatures just in excess of 100 C., the fatty acid soaps undergo abrupt transitions and are no longer capable of providing sufficient surface separation to allow shear strength measurement. The partial phosphoric ester soaps, however, exhibit smoothly decreasing shear strengths to temperatures in excess of 150 C. The shear strengths of all soaps measured increase with increasing normal pressure.

How to Put Across a Technical Paper, by L. N. Rowley, Power Magazine.

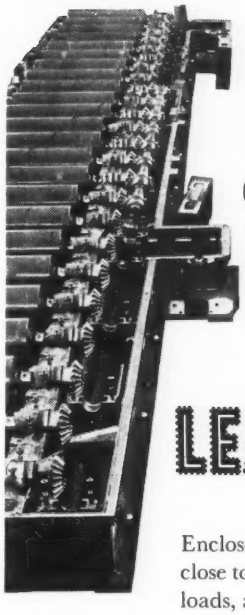
A talk intended to help engineers put their ideas across in technical meetings. Gives pointers on writing the paper, but concentrates on presentation — how the occasional speaker can achieve the illusion of a "professional" extemporaneous talk. Includes practical tips on using lantern slides, handling discussion from the floor, working with the chairman for a lively and effective meeting.

Industrial Plant Disposal Problems and their Solution, by J. W. Townsend, Consoer-Townsend & Associates.

This paper is limited to a discussion of the collecting and disposal of wastes from machine shop operations and plating and allied installations with particular emphasis on Petroleum Products. A description of methods for collecting and conveying industrial wastes to a central location for treatment is presented; several processes that have successfully treated industrial plant wastes resulting in the removal of soluble and insoluble oils, with be described.

Laboratory Test for Evaluation of Metal-Forming Lubricants, A, by R. S. Barnes & T. H. Cafcas, Standard Oil Co. (Ind.).

Lubricants for metal-working operations are difficult to evaluate in the field. Stamping, drawing and rolling mills are not well suited to rapid comparison of experimental lubricants. Present laboratory tests do not correlate well with field experience. The Instron Tensile-Test Machine has been adapted for use in evaluating metal-forming lubricants. Forcing a metal through the die attached to one of the strain-gage cells affords a measure of the performance of the lubricant under test. Most forming operations can be studied by proper choice of test-piece size and die design. Effects of temperature on the operation can also be determined. Usefulness of the test is somewhat limited by the low speed range of the machine. Evaluation of several



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lubricants by this test agrees with performance in the field. New factors have been revealed that should aid in developing better lubricants.

Limiting Bulk Fluid Temperatures for Effective Boundary Lubrication by Synthetic Lubricants, by S. F. Murray, R. L. Johnson, & E. E. Bisson, NACA, Lewis Flight Propulsion Lab.

Friction studies were conducted with boundary lubricated steel specimens at low speeds and high initial surface stresses in various bulk lubricants at temperatures increased to the point of surface failure. The relation of failure to possible lubrication mechanisms suggest a dependence of lubrication failure on thermal stability of the fluid. No correlation could be made between failure temperature and the viscosities of the various fluids at their failure temperatures. The separate effects on lubrication of the different types of conventional additives used in compounding a typical diester type lubricant was determined. A silicate ester showed more promise for high temperature lubrication than the other fluids studies; no lubrication failure was observed at temperatures approaching its decomposition point.

Measured Oil Film Pressure Distribution in Misalined Plain Bearings, by F. W. Ocvirk, Cornell University.

Under the sponsorship of the National Advisory Committee for Aeronautics, an experimental investigation was conducted at Cornell University to determine the effect of misalinement on the oil film pressure distribution of a plain bearing. Photographs are shown of five plaster models representing averaged film pressure distribution data for cases with and without misalinement. The film pressure data were obtained from seven small pressure sampling holes in the bearing wall located in a line parallel to the bearing axis. Pressures were read from high pressure gages connected to the sampling holes. By rotating the bearing shell containing the sampling holes, it was possible to measure pressures for a circumferential angle of 130° on the loaded side of the bearing while the shaft was rotating.

Microchemical Techniques in the Diagnosis of Lubrication & Wear Problems, by W. E. Campbell, Brush Labs Co., Div. of Clevite Corp.

In studying problems involving excessive wear, microscopic examination of the surfaces followed by analysis of the material formed by the rubbing action is frequently the key to the solution. The scheme for this examination which has been found successful in the Bell Telephone Laboratories is described and examples are given of its application to several specific problems. Steps in the procedure which are described are as follows: (1) Sampling, (2) Microscopic examination of wear track, (3) Replica techniques, (4) Sludge analysis scheme, and (5) Use of paper techniques in analysis of sludge.

Panel Discussion on Synthetic Lubricants, by F. Hardy, Bell Telephone Laboratories, Inc.

The first applications of synthetic lubricants in the Bell System and for the Military are discussed. Without synthetics, it would have been impossible to meet the extreme temperature requirements set by the Military for the operation of the mechanical parts associated with electronic equipment. The large savings in time and money realized by the use of synthetics are discussed. Examples are noted

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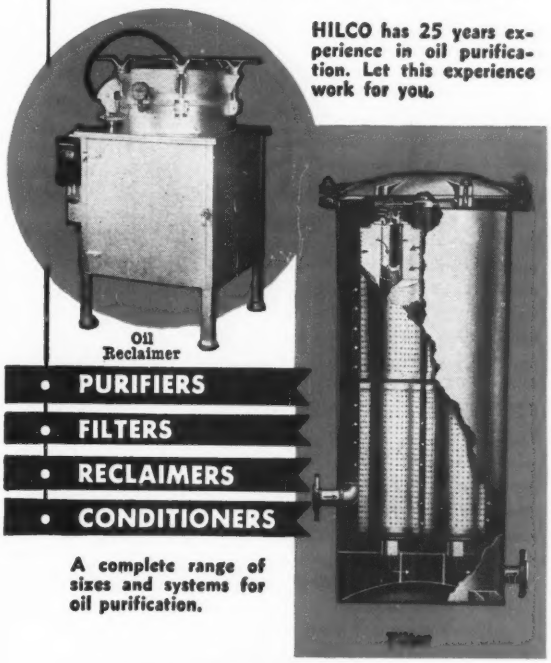

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of their application for military and industrial uses, also their effects on various rubbers and finishes and their compatibility with other lubricants. Several lubrication problems awaiting the further development of synthetics are discussed.

Planned Lubrication as a Part of Preventive Maintenance at Cadillac, by A. C. McKeen, Cadillac Motor Car Div., GMC.

Shows how a complete department is studied and the planned lubrication program developed. The polishing department at Cadillac which polishes before and after the various plating operations has been selected as the subject of the study. Along with this, will be shown how methods changes have affected the efficiency of the operation.

Polyalkylene Glycol Synthetic Lubricants, by W. H. Millett, Carbide & Carbon Chemicals Co.

The polyalkylene glycol derivatives have been widely accepted by industrial and lubrication engineers because of their unique performance characteristics coupled with the fact that they can be readily and economically synthesized on a commercial scale. They are characterized by high viscosity indexes and low pour points and can be prepared in any desired viscosity range. Some of the properties that have made these products particularly suited for industrial service are their inherent resistance to the formation of sludge and carbonaceous deposits, their clean "burn-off" when subjected to elevated temperatures for prolonged periods and their favorable load-carrying capacity and antiwear properties. In addition, they can be used with essentially all types of synthetics or natural rubbers without excessive swelling or softening.

Reaction of Adsorbed Stearic Acid with Copper & Copper Oxide, The, by A. Dobry, Westinghouse Electric Corp.

Thermodynamic calculations indicate that stearic acid should react with cuprous and cupric oxide and also with copper under oxidizing conditions, but that under inert or reducing conditions copper will not react. It was found that copper would not react with stearic acid in a hydrogen atmosphere, but that copper (presumably covered by an oxide layer) would react in air. However, only about one-fourth of an adsorbed layer of stearic acid reacts initially, contrary to the findings of other investigators.

Reclamation of Industrial Petroleum Products, by C. H. Palmer, Diesel Equipment Div., GMC.

The paper approaches the subject of oil reclamation from the viewpoint of the equipment user and discusses some of the factors serving to influence Management's decisions on reclamation programs. The paper describes the equipment being used to handle three different products and the manner in which each process fits into plant operations. Data based on operational records is included to show the advantages and total savings realized from the three reclamation systems.

Reclamation of Used Wash Solvents, by J. H. Hills, Hills & Morrow, Inc.

This paper indicates the potential economies of solvent reclamation, outlines usual procedure for surveying its possibilities in plants, the advantages often attendant to the solvent savings and cost, the general processing and equipment involved and its logical application to the varying problems encountered. Many plants are saving from hundreds up into the thousands of dollars monthly by their application of the subject discussed.

Silicone Synthetic Lubricants, by W. H. Ragborg, Dow Corning Corp.

The first portion of the presentation will be concerned with presently available silicone lubricants. A discussion of the unique properties and limitations of these products will also be given. Examples of successful silicone lubricant applications will be included. The remainder of the discussion will be directed toward some of the research and development products in progress at the moment. Emphasis will be placed on the possibilities of these potential new synthetic lubricants. Finally, an attempt will be made to establish the present and future utility of silicones for the lubrication engineer.

Spectroscopy Applied to Analysis in the Petroleum Industry, by R. C. Pomatti, R. F. Meeker, & H. Levin, The Texas Co., Beacon Laboratories.

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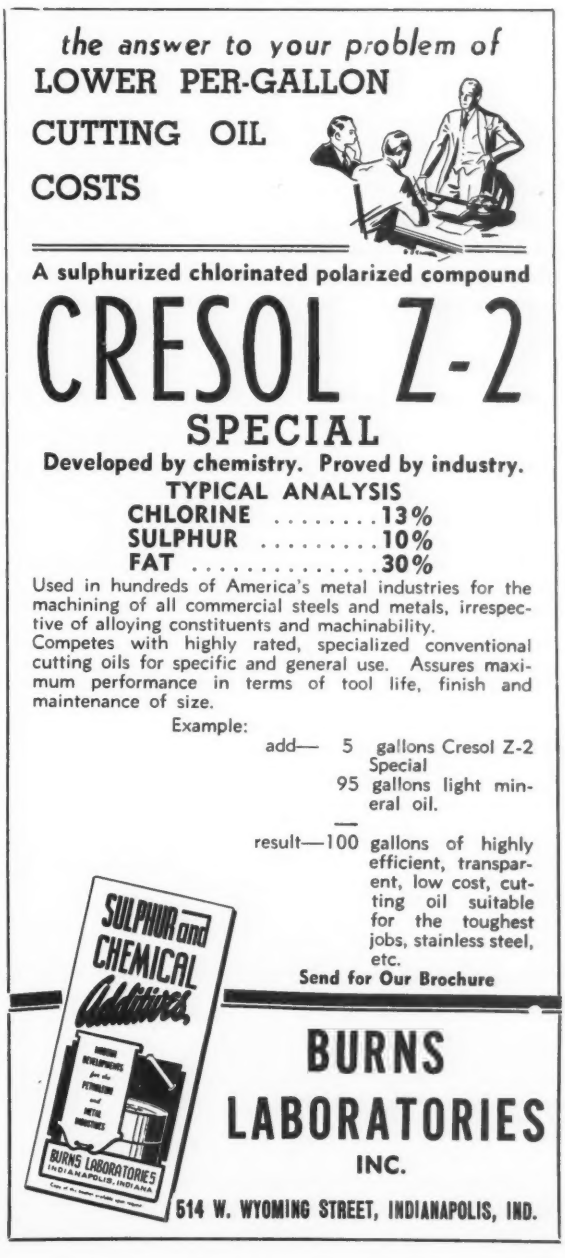
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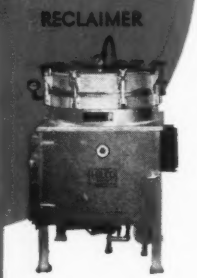

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This paper states briefly the principles of spectroscopy. The uses and advantages of spectroscopic methods as applied to analysis in a petroleum laboratory are described. Certain aspects of absorption and emission methods and instruments are discussed. Several specific applications are given.

Static Water Drop Corrosion Test, by E. J. Schwoegler & L. U. Berman, Armour Research Foundation.

A new corrosion test, the Static Water Drop Test, developed at the Naval Research Laboratories has shown considerable potential for evaluating polar compounds as corrosion inhibitors. Inconsistent data are obtained using the NRL method, so an intensive study has been made of this new method and the difficulties encountered with this method have been overcome by careful preparation of test specimens. The details of the specimen preparation and the techniques required to give excellent accuracy and precision are presented.

Study of Fretting Corrosion, A, by E. E. Weismantel, Westinghouse Electric Corp.

The purpose of this report is to consolidate data from various sources into one paper as an aid in an understanding of the fretting problem for those concerned. Because there seems to be a great deal of ambiguity concerning fretting phenomenon, this report presents the currently accepted theories and also presents the major arguments against each of these theories. The results of experimental testing and a new hypothesis, concerned with a fatigue failure of the surface, is presented. An analysis is made of the nature of active forces on the mating surfaces. This new hypothesis is offered as a possible explanation of the primary failure responsible for fretting corrosion.

Surface Active Rust Preventives in Lubricating Oil, by D. W. Criddle, California Research Corp.

The alteration of the spreading properties of an oil on a water substrate by a judicious choice of surface active materials is summarized. The similarity between an oil-water and an oil-metal interface is discussed. Some conventional lubricating oil rust preventives are examined in the light of the spreading properties they impart to the lubricant. The mechanism of rust prevention by lubricant additives is clari-

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fied by considering the spreading of a lubricant on water in addition to the conventional consideration of the metal-oil interfacial film.

Wax Coolants & Heat Dispersion, by F. C. Kraatz, S. C. Johnson & Son, Inc.

A semi-technical discussion of water based, wax type coolants for metal cutting. Paper will present information obtained through several years of production experience, with emphasis on cooling theories of wax coolants. A 5-minute colored movie demonstrating the cooling efficiency of wax coolants will be shown.

Wire Drawing Lubricants — From Raw Material to Finished Compounds, by L. Salz, Magnus Chemical Co., Inc.

The study of wire drawing lubrication has received less attention by research technologists than most other fields of lubrication. Few articles have been written on the subject and little is generally known about the composition and requirements of wire drawing lubricants. The purpose of this paper is to review the subject so that those less familiar with this specialized field will have a better understanding of the products available and their respective applications.

X-Ray Spectroscopy in the Analysis of Lubricating Oils, by R. A. VanNordstrand & E. N. Davis, Sinclair Research Laboratories, Inc.

The physics of X-ray fluorescence analysis is discussed as it pertains to both aqueous and oil systems. The sensitivity for elements of atomic number 20 and higher in oil and in water solutions is described as a function of atomic number. Methods of semi-quantitative analysis are described which do not require prior calibration curves for the elements concerned. These are of special importance when accurate analysis for one element requires corrections for the effects of interfering elements. Applications to lubricating oil technology include: (1) Control analysis in manufacture of lubricating oils, (2) Survey analysis of various types of lube oils, (3) Additive depletion studies during service of lube oils, and (4) Wear metals analysis during service of lube oils.

(Lube in the News, from p. 83)

Low Temperature Lubricating Oil. Winsor Lube LS-252 is a new light, synthetic lubricating and preservative oil intended primarily for the lubrication of equipment at low temperatures. Suitable for the lubrication of all critical equipment, such as aircraft instruments, bearings, electronic equipment, firearms, controls, etc., down to temperatures of minus 70 F., in addition to its good viscosity temperature properties this oil has goon corrosion resistance, excellent oxidation stability and a minimum effect on non-ferrous metals. For further information, write: F. E. Anderson Oil Co., Inc. (LE10/2), Portland, Conn.

Portable Production Sprayer. Produced for economical, large scale and mass production pre-lubrication of moving parts of internal combustion engines in shops, garages, engine rebuilders, and factories, a new portable dgf-123 self-pressurized Production Sprayer has been developed that operates without a compressor or other mechanical or electrical power. In effect, a giant "bug bomb" dispenser with hose and gun, the sprayer contains five gallons of "dry" prelubricant under pressure; the nozzle produces a full blossom type spray pattern and the hose allows for reaching a large area without moving the container. For further details, write: The AP Parts Corp. (LE10/2), Toledo 1, Ohio.

New Source for Special Valves. The Mathewson Corp., metal fabricator and manufacturer of special sealing parts, has announced entry into the field of special valves. Concentrating on swing and disc type check valves, vent, line, etc., especially designed for high temperatures, synthetic oils, fuels and chemicals, this specialized service has been set up to relieve engineering departments of time consuming new design criteria and to give prime and subcontractors a reliable, experienced, responsible source for weight saving valves with a superior, improved seal. Literature and detailed information are available by writing: Mathewson Corp. (LE-10/2), Dept. IV, 324 Hindry Ave., Inglewood 1, Calif.

Shell Mold Release Agents. Foundrymen can now choose from three newly designed silicones as shell mold release agents: LE-46 a stable emulsion stock, LS-46 a ready-to-use solution, and L-46 a modified silicone made available for users who prefer to make up parting solutions in their own plant. LE-46 Silicone Parting Emulson, easily diluted for use by simply mixing with tap water in any clean container, provides excellent pattern release, low build-

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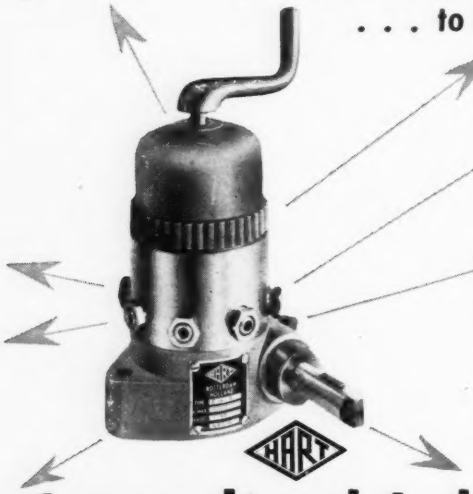

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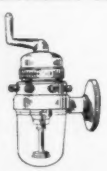
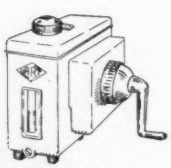
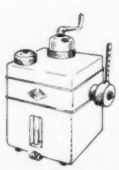


CB.R-8 Hand lubricator with transparent reservoir; capacity 0.1 liter from 1-8 outlets.



CA-16 Hand lubricator with reservoir; capacity 1 liter from 1-16 outlets.



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(Section News, from p. 79)

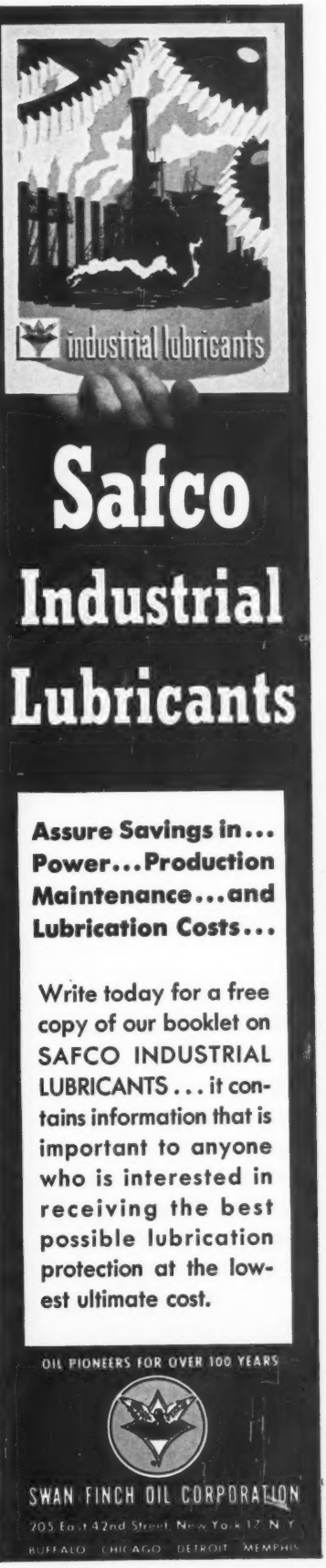
C. I. Kraus, Alemite Co. of Minnesota, presented a paper entitled Mist Lubrication, and D. Garland, Gray Co., spoke on the subject Dispensing From Original Containers. (Submitted by C. D. Johnson, Sec'y.)

(Current Literature, from p. 86)

author shows that these two types of materials form two distinct groups, showing characteristic differences in the early stages of the tempering processes, and not only in their structure but also in physical and chemical properties. Some conclusions are presented on the mechanism of crystal growth in carbon-rich compounds. The coking of coal and the pyrolysis of polyvinyl chloride and polydichloroethylene are discussed.

Studies on the Phase Separation of the System, Graphite-Mineral-Water-Oil, by E. Weingaertner & T. K. Ghose; Erdol Und Kohle, Vol. 6, No. 12, Dec. 1953, pp. 776-783.

Graphite contains certain mineral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substances, 70 or more % of which consist of silica, the remainder largely of oxides of aluminum, iron, calcium, magnesium and potassium. Removal of mineral (de-mineralization), with the use of mineral oil, is discussed Rules of liquid phase extracting were shown to be applicable, with suitable changes, to phase separation. The process is then described as separation of two or more solid phases present in the mixture, having varying wetting affinities toward two non-miscible liquid phases, with which they are mixed. Every solid phase is markedly enriched in the liquid with the higher wetting affinity and at the same time is separated from the other. This enrichment of a solid phase is investigated stepwise.

Combustion Research, Anon.; Oil Engine & Gas Turbine, Vol. 21, No. 245, Nov. 1953, pp. 262-263.

At King's College, London, investigators have worked for some years on an investigation in which a single droplet of fuel of known mass falls under gravity into a uniformly-heated chamber in which the hot air at an observed temperature is at rest, this chamber being so far under atmospheric pressure. These conditions are admittedly far from those in an engine, but, as compensating advantages, there is eliminated the interaction of one droplet on another and the effects of varying pressure, the temperature of the air in the chamber is uniform, whilst the relative velocities of droplets to air, which, of course, increase during the fall, are practically constant from test to test. Curves are given for pure and accelerated gas oil. Results obtained are summarized and will be reported in detail later.

Basis of the Lubrication Technique and the Lubrication of Combustion Motors, by F. Evers; Erdol Und Kohle, Vol. 6, No. 10, Oct. 1953, pp. 657-659.

The author discusses the tasks of the lubricating oil in motor lubrication, the theory of lubrication and the nature of modern lubricating oils. The lubricating systems of combustion engines are discussed. The article discusses the variable factors to which lubricants are subjected, such as temperature changes, high pressure, high rate of revolution and piston rate, effect of metals, dust, dirt, etc. Regeneration of lubricating oils is an individual problem, varying from oil to oil. The presence of additives is of special importance and must be taken into account in selecting a regeneration process.

The Lubrication of Ball & Roller Bearings at High Speed, by A. Fogg & J. S. Webber; Journal of the Institute of Petroleum, Vol. 39, No. 359, Nov. 1953, pp. 743-764.

This paper deals with the lubrication aspects governing the performance of rolling bearings operating in the speed range 6000 to 30,000 rpm. and under radial, thrust, and combined loading. Most of the work was carried out on standard ball bearings of 2-inch bore. Three test machines are described. Factors investigated included: effects of variation in oil feed, including reduction of oil feed to zero; a comparison of various methods of supply of lubricant; and the influence of viscosity and

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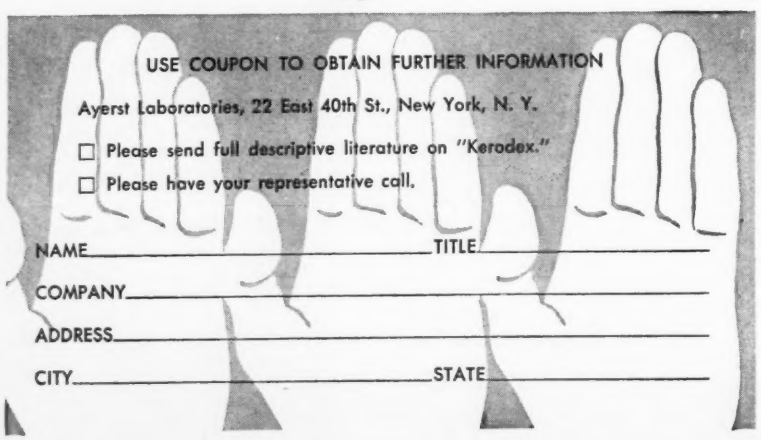
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boundary properties of the lubricant. In general, the criteria of bearing performance were temperature rise and friction.

Turbine Oils & Turbine Lubricating Oil Systems. Part III: Hydrogen Cooled Alternators, by G. H. Clark; Scientific Lubrication, Vol. 5, No. 12, Dec. 1953, pp. 10-14.

Advantages and disadvantages of hydrogen cooling are discussed. Turbine oil is used in specially designed seals or glands to prevent gas leakage. These seals are ring or thrust types, both of which are discussed. A light turbine oil can dissolve about 10 per cent of air by volume. Normally it dissolves less, however. A simplified sketch is shown of a gas control system. Seal oil and gas control systems of recent Metro-Vickers hydrogen cooled alternator are shown in a drawing, illustrating how a seal oil system can be simplified.

Wire Rope Lubricants, Anon.; Scientific Lubrication, Vol. 5, No. 12, Dec. 1953, p. 26.

The problem of the lubrication of wire rope cores is a dual one. Whatever is used must be capable of protecting the surface from corrosion—particularly the area where the main strands are in contact with the core—and also be of such a nature that it will be retained over the whole length despite the high pressures experienced which tend to squeeze it out. For this reason solid lubricants are normally used. Most published matter appears to deal only with the manufacture and properties of the ropes themselves. Sodium benzoate is a rust preventive but not a lubricant. Iso-cholesterol would not be an ideal lubricant but it could be incorporated into one.

Interaction Between Synthetic Polymers and Detergent Agents, by Sh. Shaito; Kolloid Zeitschrft, Vol. 133, No. 1, Oct. 1953, pp. 12-16.

The mechanism of the solubilization of polymers in solvents of different types has been studied, using polyvinyl acetate and polyvinyl alcohol as the model materials, and anionic, cationic and non-ionic detergents. It has been found that ionic detergents produce a palyvinyl acetate solution, which is molecular disperse. The author conjectures that such detergents cause the polyvinyl-acetate- or polyvinyl-alcohol molecule (in water) to de-coil partially its coils. Non-ionic detergents have no such effects. The interaction between polymer and detergent is always specific; the length of the detergent molecule may be one of the controlling factors.

Relationship Between Characterization Factor & Viscosity Index, by W. L. Nelson; Oil & Gas Journal, Vol. 52, No. 28, Nov. 16, 1953, p. 346.

Although it is usually believed that raw paraffinic or high-characterization-factor crude oils contain lubricating oils of high viscosity index, quite the opposite may be true if the raw lube stock contains large amounts of wax. A plot showing the general relationship between the characterization factor and viscosity index of lubricating oil fractions is given.

Fuels & Lubricants Solve Cold Weather Driving Problems, by J. A. Miller; SAE International West Coast Meeting, Vancouver, Canada, Aug. 17-19, 1953, 14 pp.

Diesel-powered railroads and gasoline and Diesel trucks and busses operate on year-round schedules in Alaska and Canada. This paper describes the special fuels and lubricants developed to permit satisfactory operation of this equipment at very low am-

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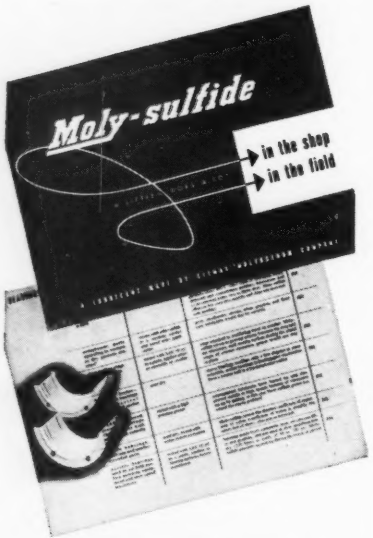

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bient temperatures and shows how winterization can be used to improve winter driving in all areas. Starting aids include heaters of both the hot air and immersion type, priming systems employing volatile fuels, flame ignition, and ether-base starting fluids. Gear lubricants and greases are discussed.

Your Engine Can Be Cured of Acid Indigestion, by W. G. Nostrand, SAE International West Coast Meeting, Vancouver, Canada, Aug. 17-19, 1953, 13 pp.

The oil industry with requirements for engine operation in isolated locations has turned to crude oil and well head gas, since the initial cost of refined fuel combined with the greatly increased transportation cost has made operations of these same engines economically impractical. The actual per cent of sulfur compounds in a fuel is not as important as in the condition of these compounds. They must be in a dissolved form in order that they become active or corrosive within the engine. After several years of laboratory and field research, the Winslow Engineering Co. has evolved a method of filtering and processing crude and residual oils. Typical installations are shown. Simple adequate processing is now available and in use on raw fuels. Successful treating procedures of a simplified nature do not pretend to remove all of the sulphur compounds from a given fuel. They do a great extent however, remove all of the foreign contaminents contained within the body of the fuel.

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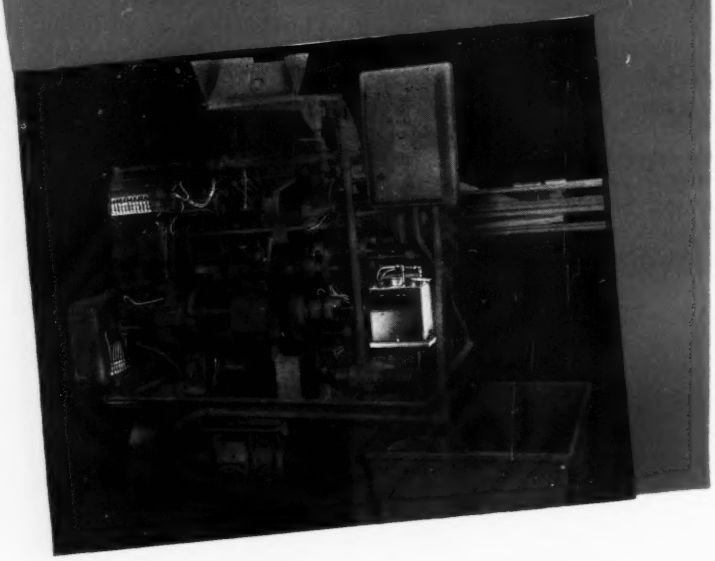

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The Measurement of Engine Wear by the Use of Radio-Isotopes, Anon.; Petroleum, Vol. 16, No. 12, Dec. 1953, p. 358.

In the past accurate measurement of wear in internal combustion engines has been a lengthy operation. Shell Petroleum Company's Thornton Research Centre scientists have evolved a faster and accurate means of deducing engine wear by using radioactive isotopes. Treatment of a cast-iron piston ring in the Harwell nuclear reactor results in a small proportion of the iron atoms being transmuted to another form of iron identical in its chemical and physical properties. These radioactive isotopes of iron are left with severe strains within their atomic nuclei, each of which therefore has a certain small chance of disintegrating with an accompanying short burst of a very penetrating form of X-rays. By counting the radio-active disintegrations within the oil it is thus possible to measure the wear arising from the piston ring alone. Precautionary measures, test equipment and results of wear measurement are discussed, as well as application of these measurements in matching oils to their conditions of use. The new ability to study the detailed mechanism of wear should greatly increase understanding of its mode of action and may lead to new ways of combating it.

Coming Events

APRIL

12-15 Society of Automotive Engineers (National Aeronautic Meeting), Statler Hotel, New York, N. Y.

13 Joint ASTM-TAPPI meeting (New York District), New York, N. Y.

14-16 National Petroleum Association (51st Semi-annual Meeting), Cleveland Hotel, Cleveland, Ohio.

18-20 American Society of Mechanical Engineers (Spring meeting), Baltimore, Md.

25-26 American Society of Mechanical Engineers (IRD Conference), Univ. of Mich., Ann Arbor, Mich.

MAY

3-5 American Petroleum Institute (Lubrication Committee), Skytop Lodge, Skytop, Pa.

3-5 American Geophysical Union (35th Annual Meeting), Nat'l. Academy of Sciences, Washington, D. C.

16-19 American Institute of Chemical Engineers, Springfield, Mass.

20-21 National Industrial Conference Board (38th Annual Meeting), Waldorf-Astoria Hotel, New York, N. Y.

JUNE

6-11 Society of Automotive Engineers (Summer meeting), Ambassador & Ritz-Carlton Hotels, Atlantic City, N. J.

13-18 American Society for Testing Materials (Annual Meeting & Exhibit), Sherman & Morrison Hotels, Chicago, Ill.

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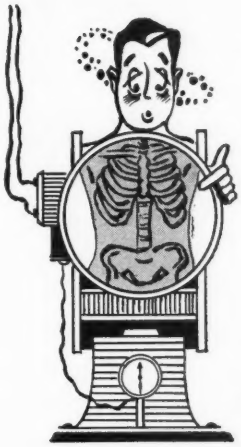

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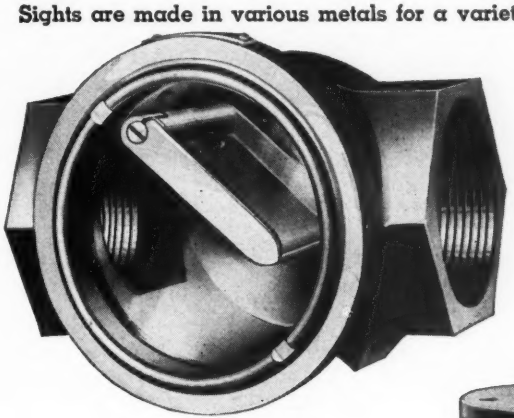

FIG. 811

FIG. 811

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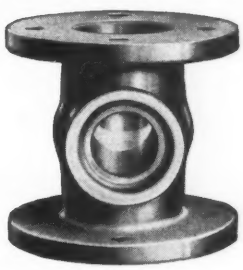

FIG. 54A

FIG. 54A

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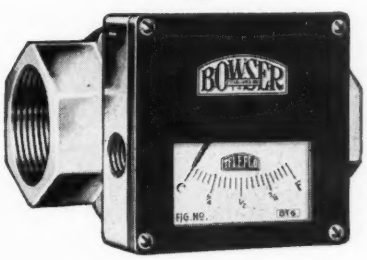

FIG. 816

FIG. 816

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Farval lubrication holds transfer machine to continuous production

THIS Ex-Cell-O transfer machine is in a famous automobile engine plant. Its job is precision boring of the main bearing line (held to 0.0005 inch tolerance), the cam line (held to plus or minus 0.001 inch) and the distributor bore. It is built to operate at top speed, with uniform precision and efficiency.

To avoid shutdowns for oiling and for bearing repairs that accompany haphazard methods of hand lubrication, a Farval automatic lubricating system was installed. Farval lubricates while the machine is in full operation, entirely eliminating downtime for oiling, increasing bearing life, and allowing higher machine speeds by keeping bearings cooler.

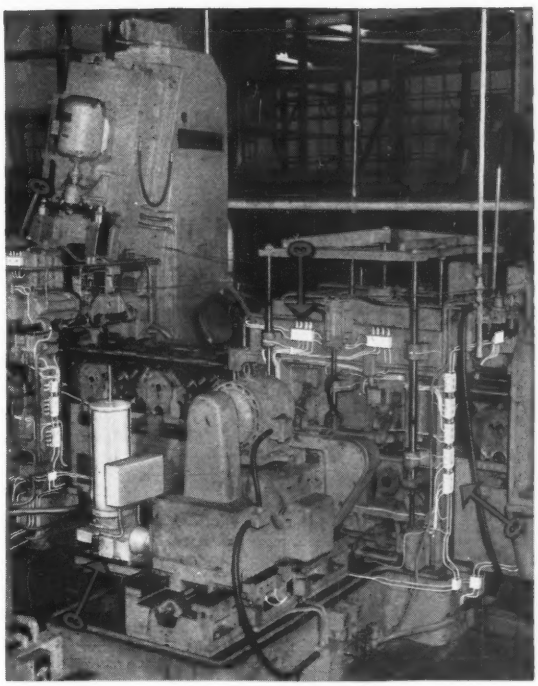
Farval is the original Dualine system of centralized lubrication that delivers oil or grease under pressure to a group of bearings from one central station, in exact quantities, as often as desired. The Farval valve has only two moving parts—is simple, sure and foolproof, without springs, ball-checks or pinhole ports to cause trouble. The easy-to-see indicators at every bearing show that each valve has functioned.

Today Farval protects millions of bearings in the automobile and allied industries, wherever equipment must be lubricated regularly and adequately to keep bearings on the job no matter how hard to get at.

Find out how Farval can help keep your equipment running continuously for maximum production. Write today for free Bulletin 26. The Farval Corporation, 3267 E. 80th St., Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Co., Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

FARVAL—*Studies in Centralized Lubrication*
No. 146



KEYS TO ADEQUATE LUBRICATION—Wherever you see the sign of Farval—the familiar valve manifolds, dual lubricant lines and central pumping station—you know a machine will be properly lubricated. Illustration by courtesy of Automotive Industries.

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LOAD-N-KOTE LUBRICANT

LOAD-N-KOTE LUBRICANT — a formulation which is being received very enthusiastically by industry as an open gear lubricant, cable dressing, roll coating, spare part storage coating, etc.

LOAD-N-KOTE LUBRICANT is of the "cut-back" or solvent type, which is easily dispensed with the HODSON PORTABLE LUBRICANT DISPENSER. While equipment is in motion the material plates out very rapidly, resulting in an even protective coating.

LOAD-N-KOTE LUBRICANT adheres readily to cleaned or uncleaned surfaces, covering the area with a tacky, tenacious film that will not flake off in extreme temperatures, nor melt at high ambient temperatures.

LOAD-N-KOTE LUBRICANT is also of the E.P. (extreme pressure) family, passing the 4 gram test at the full 43# load for 30 minutes. It also passes the copper corrosion test — Negative.

These features, along with the low pour test, brings about an ideal formulation which results in enormous savings in amounts used — approximately 100 sq. ft. to a pint.

HODSON PORTABLE LUBRICANT DISPENSER

In connection with LOAD-N-KOTE LUBRICANT our laboratories have developed the HODSON PORTABLE LUBRICANT DISPENSER which is operated free of any electric cords, hose, etc., and being an entirely portable unit, it may be powered from the plant air line.

The HODSON CORPORATION

Lubrication

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